

Memoirs of the Queensland Museum | **Nature** **61**

© The State of Queensland, Queensland Museum 2018

PO Box 3300, South Brisbane 4101, Australia

Phone 06 7 3840 7555

Fax 06 7 3846 1226

Email qmlib@qm.qld.gov.au

Website www.qm.qld.gov.au

National Library of Australia card number

ISSN 0079-8835 Print

ISSN 2204-1478 Online

NOTE

Papers published in this volume and in all previous volumes of the *Memoirs of the Queensland Museum* may be reproduced for scientific research, individual study or other educational purposes. Properly acknowledged quotations may be made but queries regarding the republication of any papers should be addressed to the Editor in Chief. Copies of the journal can be purchased from the Queensland Museum Shop.

A Guide to Authors is displayed at the Queensland Museum web site www.qm.qld.gov.au

A Queensland Government Project

Typeset at the Queensland Museum

A revision of *Gyrocochlea*-grade Charopidae from mid-eastern Queensland and redescription and generic reassignment of three *Gyrocochlea*-grade species (Eupulmonata: Charopidae)

Lorelle HOLCROFT

School of Environment and Science, Griffith University; Australian Rivers Institute. Email: lorelle.holcroft@griffithuni.edu.au; lorelle.holcroft@bigpond.com

Citation: Holcroft, L. 2018: A revision of *Gyrocochlea*-grade Charopidae from mid-eastern Queensland and redescription and generic reassignment of three *Gyrocochlea*-grade species (Eupulmonata: Charopidae). *Memoirs of the Queensland Museum – Nature* 61: 1–28. Brisbane. ISSN 0079-8835 (Online), ISSN 2204-1478 (Print). Accepted: 14 January 2018. First published online: 30 April 2018

<https://doi.org/10.17082/j.2204-1478.61.2018.2017-14>

LSID urn:lsid:zoobank.org:pub:8D81529E-3CA8-44FA-9AAB-6C63201074C9

ABSTRACT

This study reviews the *Gyrocochlea*-grade charopid snails of mid-eastern Queensland. *Gyrocochlea auct.*, characterised by brown, biconcave shells with a diameter of 3–7 mm, has been shown to be polyphyletic (Shea *et al.* 2010). *Gyrocochlea* s.s. is confirmed as a genus geographically restricted to the Border Ranges of south-east Queensland and north-eastern New South Wales (Stanisic 1990). This study utilised scanning electron microscopy of the shell architecture, qualitative and quantitative measurements of conchological features and anatomical dissection where suitable specimens were obtainable. Based on shell morphology, primarily protoconch sculptural patterns (as defined in Holcroft 2018), this study re-assigns three *Gyrocochlea*-grade species, *G. chambersae* (Stanisic, 2010), *G. iuloidea* (Forbes, 1851) and *G. danieli* (Stanisic, 2010) to three new genera, *Stanisicaropa* gen. nov., *Whitcochlea* gen. nov. and *Radiolaropa* gen. nov. respectively and diagnoses four new genera, *Amfractaropa* gen. nov., *Comularopa* gen. nov., *Nodularopa* gen. nov. and *Xenoropa* gen. nov. Five new species are described: *Nodularopa samantha* sp. nov., *Amfractaropa bretti* sp. nov., *Comularopa georginae* sp. nov., *Radiolaropa eungella* sp. nov., and *Xenoropa wigtonensis* sp. nov. □ Mollusca, Eupulmonata, Charopidae, *Gyrocochlea*, protoconch sculpture, new genera, new species.

The Charopidae (Pinwheel Snails) is a speciose family of tiny snails (shell diameter from 1–7 mm) of Gondwanan origin (van Bruggen 1980) inhabiting rainforest environments of many of the land masses of the Southern Hemisphere but is particularly diverse in eastern Australia (Queensland, New South Wales, Victoria and Tasmania). The family does occur, but less frequently, in South Australia, Western Australia and central Australia (Smith 1992; Stanisic *et al.* 2010, 2017). Of an estimated 750

Australian charopid species, only approximately 25% have been described, causing a taxonomic backlog within this family which needs to be resolved (Hyman & Stanisic 2005; Stanisic *et al.* 2010, 2017; Shea *et al.* 2012; Stanisic 2016).

A major group of charopids in eastern Australia are the *Gyrocochlea*-grade species (Stanisic 1990; Stanisic *et al.* 2010; Shea *et al.* 2012; Holcroft 2017, 2018). *Gyrocochlea*-grade charopids are a group of species characterised

by typically brown, biconcave shells with a diameter of 3–7 mm (generally less than 5 mm) and a strong, radially-ribbed teleoconch (Shea *et al.* 2012). Species inhabit rainforests, both wet and dry, where they play a significant role in maintaining the environmental health of the ecosystem (Stanisic 1990, 1998). Species prefer to live under logs, rocks and in the leaf litter of rainforests (Bishop 1981; Stanisic 1994; Stanisic & Ponder 2004; Hyman & Stanisic 2005).

From an initial 11 species of *Gyrocochlea* described by Hedley (1924) the number had grown to 34 species in Stanisic *et al.* (2010) which included 22 newly described. Shea *et al.* (2012) in a molecular and morphological study of *Gyrocochlea* showed that *Gyrocochlea sensu stricto* was in fact restricted to a small number of species from Border Ranges of NE NSW/SEQ. Consequently eight new genera were diagnosed to accommodate 17 new and 9 previously described *Gyrocochlea*-grade species from mid-east and north-eastern NSW. Subsequently Stanisic (2016) reassigned '*Gyrocochlea*' *myora* Stanisic, 2010 from North Stradbroke Island, SEQ to a new genus.

Historically, *Gyrocochlea*-grade charopids have been known from mid-eastern Queensland (MEQ) since the 1840s with '*Gyrocochlea*' *iuloidea* described from Long I, (= Port Molle) in the Whitsunday islands by Forbes in 1851. Hedley (1912) added '*Gyrocochlea*' *recava* which Stanisic (1990) subsequently reassigned to a new genus *Biomphalopa*. Stanisic *et al.* (2010) described 9 species of pinwheel snails from the region including three new species of *Gyrocochlea*-grade charopids. However, recent investigations of the land snail collections of the Queensland Museum (Brisbane) by the author revealed an additional number of putative species of *Gyrocochlea*-grade charopids from MEQ that have yet to be described.

This study revises three '*Gyrocochlea*' species from MEQ introduced by Stanisic *et al.* (2010). All three species are assigned to new generic units based on their protoconch sculpture which differs significantly from true *Gyrocochlea* (type species. *Helix vinitincta* Cox, 1868). In addition, five new genera and species

of *Gyrocochlea*-grade charopids from MEQ are described with protoconch sculpture also differing substantially from true *Gyrocochlea*. *Biomphalopa recava* (Hedley, 1912) has been included in this study as a MEQ *Gyrocochlea*-grade species originally separated from *Gyrocochlea* s.s. by Stanisic (1990).

Delimitation of charopid genera and species

From a morphological perspective, determining generic difference in Australian Charopidae has been primarily based upon protoconch architecture (Stanisic 1990; Bonham 2003; Hyman & Stanisic 2005; Shea *et al.* 2012; Stanisic 2016; Holcroft 2018) in combination with shell coiling pattern and teleoconch sculpture. While spiral, radial and reticulate protoconch sculptures were used previously (Iredale 1937ab; Smith & Kershaw 1979; Stanisic *et al.* 2010; Shea *et al.* 2012), the more rigorous classification system and nomenclature for protoconch sculptural patterns prescribed by Holcroft (2018) provide a consistent and informative terminology in the descriptions presented in this study. Eleven major configurations of protoconch microsculpture were identified by Holcroft (2018) of which four have been applied to taxa included on this study.

Secondarily, the size and structure of genitalia may be also used to delimit genera. However, this is largely dependent on the availability of suitable material for dissection.

In the absence of animal tissue suitable for reliable molecular analysis and comparative anatomical analyses, species delimitation in this study has been based on shell morphology with the exception of two species where anatomical dissection was possible. Charopidae with very minor exceptions are rich in shell characters useful in species delimitation. Solem (1983) established criteria for such an approach. He recognised that to maintain genetic integrity, species must possess certain 'species recognition' features in the reproductive organs. In particular, Solem indicated that penial structure (size of penis and the number, shape and length of internal pilasters) was significant

in this regard. Solem also found that major differences in reproductive anatomy correlated with measurable conchological differences. This was based on the premise that genetic divergence is reflected in phenotypic alterations of the shell. As a result, Solem (1983) proposed that at least 3 non-correlated conchological differences must exist for allopatric populations to be classified as distinct species.

In this paper, strong emphasis has been placed on a number of conchological features such as shell coiling pattern, shell diameter, number of ribs on the body whorl, ratio of shell diameter to umbilical width (D/U), ratio of shell height to diameter (H/D) and number of whorls to distinguish species. In addition features relating to gross shell morphology and teleoconch sculpture (radial rib structure, rib spacing, microsculpture) have also been examined in detail.

ABBREVIATIONS

General. SEM, scanning electron microscopy; SC, spirit collection; RC, dry collection.

Institutions. AM, Australian Museum, Sydney; NHM, Natural History Museum, London; QM, Queensland Museum, Brisbane.

Habitat Data. alt., altitude; Ck, Creek; CNVF, complex notophyll vine forest; Hts, Heights; I., Island; Mts, Mountains; NVF, notophyll vine forest; R., River; Ra., Range; SEVT, semi-evergreen vine thicket; SNEVF, simple notophyll vine forest; MEQ, Mid-eastern Queensland; NENSW, North-eastern New South Wales; NEQ, North-eastern Queensland; WT, Wet Tropics; NP, National Park; NSW, New South Wales; SEQ, South-eastern Queensland; SF, State Forest.

Shell features. AH, aperture height; AW, aperture width; D, shell diameter; H, shell height; PD, protoconch diameter; T1, 1st whorl of the teleoconch; UW, umbilical width; WWB, number of ribs on the 3rd quarter of the body whorl.

Anatomical data. E, epiphallus; EP, epiphallic pore; P, Penis; PP, penial pilasters; PRM, penial retractor muscle; PS, penial sheath; VD, vas deferens.

MATERIALS AND METHODS

The study was chiefly based on material held in the Queensland (Brisbane) and Australian (Sydney) Museums. Individual specimens are identified by their registration number and respective institutional prefix (QMMO, Queensland Museum; AMSC, Australian Museum) and the private collection of Jack Worsfold (JW). Supplementary field work was conducted to collect further animal tissue suitable for dissection.

Morphological methods. Adult shells were measured using a Camera Lucida mounted on a WILD M5 stereo microscope. Measurements were converted from ocular micrometer units to mm using a conversion factor at a set magnification. Characters investigated included shell shape, size (height and diameter), whorl count, coiling pattern, rib count and umbilical width (Appendix 2). Standard definitions (Solem 1983) for most conchological characters were used and whorl counts were made to the nearest 1/8 whorl.

High resolution images of shells (260-600MB) were obtained using a Visionary Digital BK-Plus lab system camera set-up in the Queensland Museum's Digital Imaging Unit.

The shell sculpture of specimens was investigated and photographed using a TM-1000 Tabletop Scanning Electron Microscope located at the Queensland Museum. Shells were cleaned in an ultrasonic cleaner but not by chemical means in order to prevent the removal of the periostracum which maintains many of the shell's sculptural elements. Specimens were mounted on sticky tabs, gold sputter coated and imaged under high vacuum. Sculptural patterns of both the protoconch and teleoconch were extensively examined. Protoconch sculptural patterns were coded according to Holcroft (2018), viz. **pitted cancellate** (a lattice of broad spiral cords and radial ribs or ridges closely interwoven so that the distance between each is smaller than the width of the cord or rib resulting in a pitted appearance); **superior spiral** (spiral cords for only the first quarter

of a whorl followed by dominant spiral cords over raised radial ribs); **spiral** (spiral cords and no radial ribs); **early spiral** (spiral cords only for the first whorl followed by a pattern of strong radial ribs over the spiral cords for the remainder of the protoconch); **beaded cancellate** (thin interrupted spiral cords visible as round or elongate beads where they cross low radial ribs or ridges resulting in a beaded appearance).

Adult specimens of two species for which animal tissue was available, *Stanisicaropa chambersae* (Stanisic, 2010) comb. nov. and *Whitcochlea iuloidea* (Forbes, 1851) comb. nov., were submerged in a shallow container of 75% ethanol and pinned to a black latex base using very fine 'Austerlitz' entomological pins. These pins were also used as dissection implements. Shells were removed and specimens were dissected. Photographs were taken of the male reproductive system using a NIKON Coolpix 4500 camera mounted on a WILD M5 stereo microscope. Photographs were labelled to show the internal anatomy of the penis which is considered to be species specific (Solem 1983).

A summary of specimens investigated by SEM and anatomical photography is included in Appendix 1.

RESULTS AND ANALYSIS.

Shell morphology. Mean shell measurements are shown in Table 1 and all specimens measured are tabulated in Appendix 1. Each species differed from all others in at least 10 conchological features with only 3 required to consider species differentiation. The only measurement that overlapped between species was the height/diameter ratio.

Scanning Electron Micrographs. SEM images showed four major protoconch sculptural patterns. A pitted cancellate protoconch is characteristic of *Biomphalopa* Stanisic, 1990 and *Stanisicaropa* gen. nov. (Figs 1B, C). All three

forms of spiral protoconch sculpture were found *viz.* spiral, superior spiral and early spiral. Variations of a spiral protoconch were found on *Amfractaropa* gen. nov. and *Comularopa* gen. nov. (Figs 2A, B). Two slightly different superior spiral protoconchs were a feature of *Whitcochlea* gen. nov. and *Xenoropa* gen. nov. (Figs 2C, D). *Radiolaropa* gen. nov. and *Nodularopa* gen. nov. both shared an early spiral protoconch sculpture which showed variations in the number and prominence of the spiral cords and the nodulose pattern of the latter genus (Figs 1D, E, F). Genera sharing a particular protoconch sculpture were differentiated on the finer dimensions and characteristics of that sculpture together with other characteristics such as shell dimensions and anatomy. All MEQ *Gyrocochlea*-grade genera displayed a protoconch sculpture markedly different from the beaded cancellate pattern of *Gyrocochlea* s.s. (Fig. 1A).

Teleoconch microsculpture of the species exhibited both rounded ribbing on *Stanisicaropa chambersae* (predominately nodulose spiral cords over very fine radial threads) and *Biomphalopa recava* (radial threads over very fine spiral cords) and bladed ribbing in the other seven species (Fig. 3). The microsculpture of radial threads varied in number and size between species but was consistent within species including *Whitcochlea iuloidea* which occurs both on the mainland and on off-shore islands.

Anatomy. The terminal male genitalia of *Stanisicaropa chambersae* and *Whitcochlea iuloidea* were dissected (Figs 4A, B) and demonstrated two distinct penial configurations: *S. chambersae* with a pear-shaped penis lacking a penial sheath and lateral entrance of the epiphallus into the penial chamber (Fig. 5A); and *W. iuloidea* with a tubular-shaped penis with a penial sheath and apical entrance of the epiphallus into the penial chamber (Fig. 5B). Both species differed from the penial structure of *Biomphalopa recava* illustrated by Stanisic (1990).

SYSTEMATICS

ORDER EUPULMONATA

SUPERFAMILY PUNCTOIDEA

FAMILY CHAROPIDAE HUTTON, 1884

Biomphalopa Stanisic, 1990

Type species. *Endodonta recava* Hedley, 1912-by original designation.

Diagnosis. As cited in Stanisic (1990) with the re-description of the apical sculpture as pitted cancellate.

Remarks. *Biomphalopa* Stanisic, 1990 has a pitted protoconch sculpture (Fig. 2B) similar to that of *Stanisicaropa* gen. nov. (Fig. 2C) but differing in greater number of whorls and the

thickness of the radial ribs and spiral cords. The former is also distinguished from the latter genus by other aspects of shell morphology including the flammulated shell, bolder teleoconch ribbing and much wider, cup-shaped umbilicus. *Biomphalopa* differs from *Gyrochochlea* s.s. by having bolder protractively sinuated teleoconch ribs, a wider cup-shaped umbilicus and a coiling pattern that is multi-whorled in contrast to the nautiloid form of the latter. Stanisic (1990) also included *B. concinna* (Hedley, 1924) from the Wet Tropics, NEQ.

Biomphalopa recava (Hedley, 1912) (Figs 1B, 3A, 6A-B, 10, Table 1)

Endodonta recava Hedley, 1912: 267.

Gyrochochlea recava (Hedley). Hedley, 1924: 217; Iredale, 1937: 323

Biomphalopa recava (Hedley). Stanisic, 1990: 95. Smith, 1992: 182; Stanisic *et al.*, 2010: sp. 389.

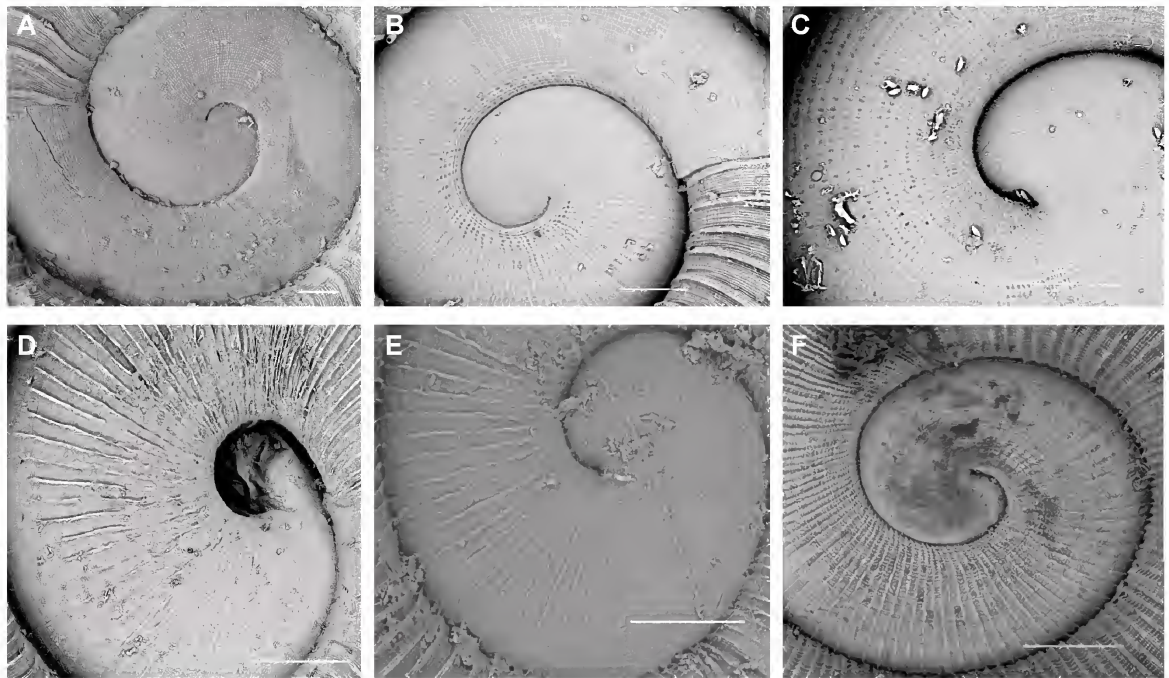


FIG. 1. Protoconch sculptures. A, Beaded cancellate: Type species of *Gyrochochlea* s.s., *Gyrochochlea vinitincta* (Cox, 1868), AMSC139752, Border Ranges, SEQ. B-C, Pitted cancellate: B, *Biomphalopa recava* (Hedley, 1912), QMMO85117, Finch Hatton Gorge, MEQ; C, *Stanisicaropa chambersae* (Stanisic, 2010) comb. nov., QMMO78961, Diggings Road, Eungella, MEQ. D-F, Early spiral: D, *Radiolaropa danieli* (Stanisic, 2010) comb. nov., QMMO35807, Endeavour Ck, MEQ. E, *Radiolaropa eungella* sp. nov., QMMO36099, Eungella Dam. F, *Nodularopa samanthae* sp. nov., QMMO77397, Upper Funnel Ck, MEQ. Scale bars = 100 μ m.

Material examined. Holotype. AMSC32992, Finch Hatton Gorge, 81 km W of Mackay, nvf under logs, coll. S. Jackson, 13.xii.1912.

Other material. Eungella: QMMO6345, 1SC; QMMO39878, 2RC; QMMO85176, 2SC; AMSC140230, 2RC; Broken R.: QMMO11715, 1RC. Diggings Road: QMMO11757, 1SC/2RC; QMMO13073, 2RC; Mt Dalrymple: QMMO36093, 1RC; QMMO6367, 1SC/1RC; QMMO77431, 3SC; QMMO85065, 1RC; Finch Hatton Gorge: QMMO11749, 1RC; AMSC153726, 1RC.

Distribution and habitat. Eungella NP, MEQ; in rainforest living under logs and other forest debris.

Remarks. *Biomphalopa recava* (Hedley, 1912) differs from all other MEQ *Gyrocochlea*-grade charopids by having a multi-whorled shell with a very wide cup-shaped umbilicus. The description detailed in Staniscic (1990) is adequate with the exception that the protoconch sculpture was described as 'regularly arranged pits and vague radial ridges' but is pitted cancellate in the new terminology proposed by Holcroft (2018). *B. recava* is a MEQ endemic species confined to the Clarke Ra. in the vicinity of Eungella NP and its environs.

Staniscicaropa gen. nov.

Type species. *Gyrocochlea chambersae* Staniscic, 2010-herein designated.

Etymology. For Dr John Staniscic in honour of his taxonomic work on Australian Charopidae; and a contraction of *Charopa*.

Diagnosis. Shell small, orange brown with darker radial bands, discoidal, nautiliform with a slightly sunken spire; protoconch pitted cancellate, pits formed by intersecting broad, low spiral cords and broad, low radial ridges of equal height; teleoconch with moderately spaced, broad, bold radial ribs and microsculpture of very crowded, very low microradial threads continuous on the major ribs and low microspiral cords forming beads at their intersection, spiral cords rolling over the major ribs; aperture ovately lunate; umbilicus wide cup-shaped; epiphallus long, entering penis laterally, penis pear-shaped with longitudinal pilasters.

Remarks. *Staniscicaropa* gen. nov. differs from *Gyrocochlea* s.s. by having a pitted protoconch sculptural pattern (Fig. 1C) which contrasts markedly with the fine, beaded cancellate pattern seen in the latter (Fig. 1A). This difference is of similar magnitude to the differences between *Gyrocochlea* s.s. and some of the new genera of Shea *et al.* (2012) and is therefore considered sufficient justification for the description of a new genus to accommodate '*Gyrocochlea*' *chambersae* Staniscic, 2010. The genus appears to be endemic to MEQ (Staniscic, pers. comm.).

Staniscicaropa chambersae

(Staniscic, 2010) comb. nov.

(Figs 1C, 3B, 4A, 5A, 6C-D 10, Table 1)

Gyrocochlea chambersae Staniscic, 2010 (in Staniscic *et al.* 2010, sp. 295)

Material examined. Holotype. QMMO11758, Diggings Rd Eungella NP, 21°09'S, 148°29'E, nvf, coll., J. Staniscic, 8.vii.1982.

Paratypes. QMMO11714, 2SC/3RC, Eungella NP, Broken R., 21°10'S, 148°30'E, nvf, coll., J. Staniscic, 5.vii.1982; QMMO13071, 1RC, same data as holotype; QMMO13456, 1RC, Eungella NP, Broken R., 21°10'S, 148°30'E, nvf, coll., J. Staniscic, 5.vii.1982; QMMO50888, 1RC, Eungella NP, Rocky Ck, 20°54'S, 148°35'E, coll., ANZES, 27.xii.1993; QMMO78961, 10SC, same data as holotype.

Other Material. Eungella NP: QMMO20224, 1SC; QMMO77427, 1SC; QMMO85102, 1RC; QMMO85113, 1SC; QMMO85118, 2SC; QMMO85119, 1SC; QMMO85120, 1SC; QMMO85121, 1SC; QMMO85122, 2SC; QMMO59648, 1RC; QMMO85174, 2SC. Broken R.: QMMO6375, 5SC; QMMO6377, 1SC; QMMO77435, 1SC. Pease's Lookout: QMMO85111, 1SC; QMMO85073, 1RC. Finch Hatton Gorge: QMMO85115, 1SC; Crediton Ck: QMMO6356, 2SC; QMMO85344, 3SC. Mt Macartney: QMMO35619, 1RC.

Diagnosis. As for genus.

Description. Shell small, orange brown with darker radial bands, discoidal, nautiliform with a slightly sunken spire; whorls 4.00–4.5 (mean 4.2); sutures moderately impressed; diameter of shell 3.5–4.4 mm (mean 3.99 mm), height 2.01 to 2.4 mm (mean 2.2 mm); H/D 0.51–0.61 (mean 0.55). Protoconch flat, 1.5 whorls, diameter 490–660 µm (mean 550 µm), pitted cancellate consisting of broad spiral cords and broad radial ridges, teleoconch with moderately

TABLE 1. Mean shell measurements of MEQ *Gyrochochlea*-grade species examined in this study.

Taxon	n	D	H	UW	AH	AW	PD	WWB	T1	H/D ratio	D/U ratio	No. whorls
<i>Amfractaropa bretti</i>	6	3.14	1.64	0.85	1.3	1.11	0.49	41	104	0.54	3.70	4.00
<i>Biomphalopa recava</i>	7	3.89	2.21	1.87	1.85	1.09	0.55	22	40	0.57	2.09	4.375
<i>Comularopa georginae</i>	1	2.30	1.31	0.66	0.90	0.66	0.41	66	132	0.57	3.50	3.875
<i>Nodularopa samanthae</i>	2	3.20	1.84	1.19	1.72	1.39	0.49	43	78	0.58	2.68	4.125
<i>Radiolaropa danieli</i>	3	3.17	1.80	1.26	1.50	1.17	0.49	42	79	0.61	2.57	3.75
<i>Radiolaropa eungella</i>	2	3.03	1.60	1.15	1.35	1.02	0.49	39	91	0.53	2.66	4.00
<i>Stanisicaropa chambersae</i>	13	5.04	2.78	1.65	2.11	1.65	0.55	20	53	0.55	3.08	4.25
<i>Whitcochlea iuloidea</i>	68	4.65	2.48	1.68	1.96	1.54	0.59	25	49	0.53	2.75	4.25
<i>Xenoropa wigtonensis</i>	2	6.02	2.87	2.01	2.09	2.01	0.78	52	67	0.48	3.00	4.375

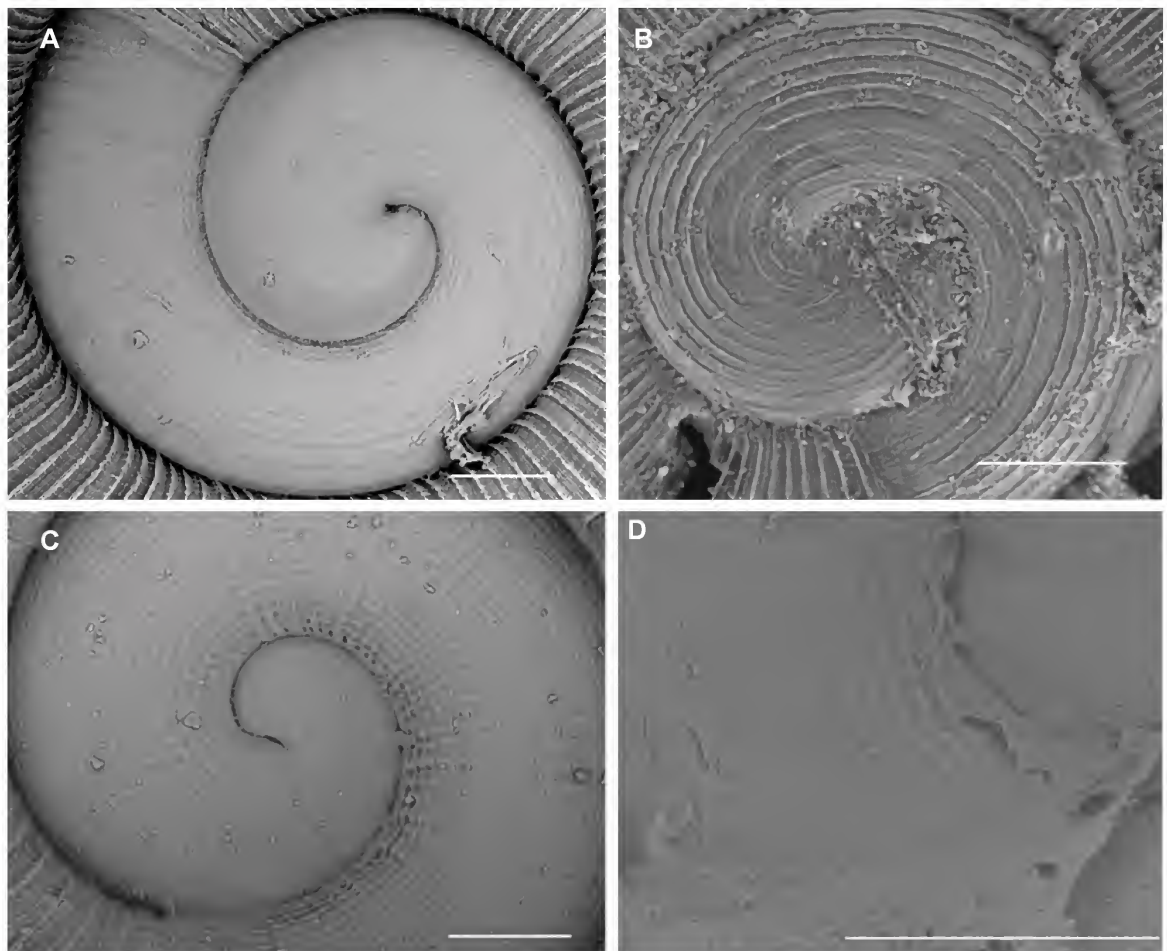


FIG. 2. Protoconch sculptures. **A-B**, Spiral: **A**, *Amfractaropa bretti* sp. nov., QMMO11716, Broken R., MEQ; **B**, *Comularopa georginae* sp. nov., QMMO59645, Crediton Ck, MEQ. **C-D**, Superior spiral: **C**, *Whitcochlea iuloidea* (Forbes, 1851) comb. nov., QMMO6342, Brandy Ck, Conway Ra., MEQ. **D**, *Xenoropa wigtonensis* sp. nov., QMMO85180, Wigton I., MEQ. Scale bars = 100 μm.

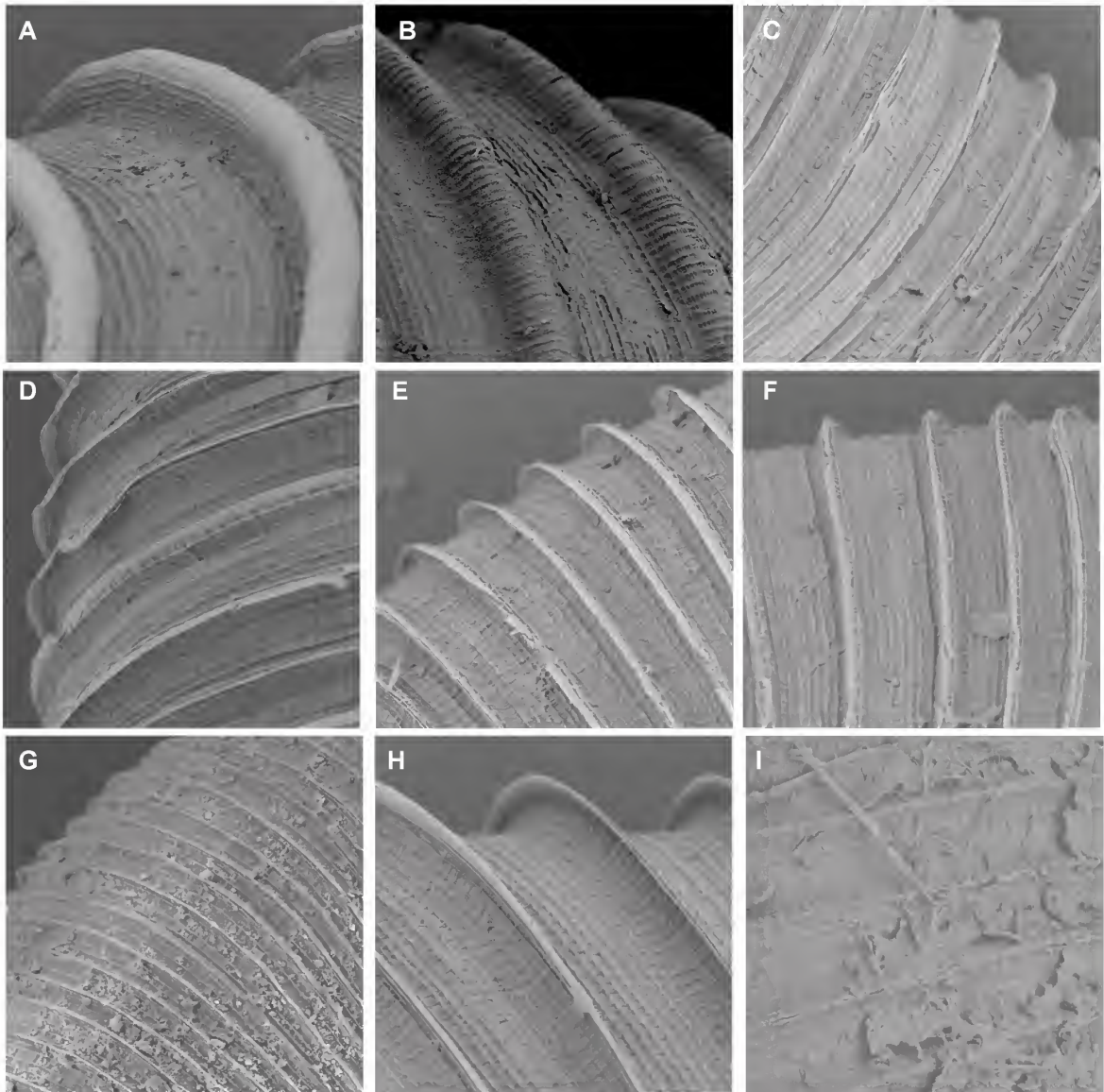


FIG. 3. Teleoconch sculpture. **A**, *Biomphalopa recava* (Hedley, 1912), QMMO39878, Finch Hatton Gorge, MEQ. **B**, *Stanisicaropa chambersae* comb. nov., QMMO78961, Eungella, MEQ. **C**, *Radiolaropa danieli* (Stanisic, 2010) comb. nov., QMMO35807, Endeavour Ck, MEQ. **D**, *Radiolaropa eungella* sp. nov., QMMO36099, Eungella Dam. **E**, *Nodularopa samanthae* sp. nov., QMMO77397, Upper Funnel Ck, MEQ. **F**, *Amfractaropa bretti* sp. nov., QMMO11716, Broken R., MEQ. **G**, *Comularopa georginae* sp. nov., QMMO59546, Crediton Ck, MEQ. **H**, *Whitcochlea iuloides* (Forbes, 1851) comb. nov., QMMO85334, Brandy Ck, Conway Ra., MEQ. **I**, *Xenoropa wigtonensis* sp. nov., QMMO70431, Wigton I., MEQ. All magnification 600X.

spaced, bold radial ribs, 42-61 (mean 53) on the first whorl; microsculpture of extremely fine microradial threads and low, spiral cords forming beads at their intersections with the microradials, rolling unbroken over the major teleoconch ribs; aperture ovately lunate; umbilicus wide cup-shaped, diameter 1.00-1.46 mm (mean 1.3 mm), DU 2.6-3.7 (mean 3.08). Based on 13 measured adult specimens.

Terminal male genitalia (Figs 4A, 5A). Vas deferens-epiphallus junction a ball and socket arrangement; epiphallus long, longer than penis, initially swollen becoming thinner approaching the penis, bound to penis head in the vicinity of the penial retractor muscle attachment, before descending and entering penis laterally through a simple pore with a muscular collar. Penis pear-shaped, internally with longitudinal pilasters; length 1.69 mm. Based on one dissected specimen (QMMO78961).

Distribution and habitat. Eungella to Mt Macartney. Clarke Ra., MEQ, in moist humid rainforest living under logs.

Remarks. *Stanisicaropa chambersae* (Stanisic, 2010) comb. nov. can be readily distinguished from other MEQ *Gyrocochlea*-grade species by the combination of pitted cancellate protoconch and more intense microradial ribbing rolling over the major ribs on the teleoconch (Figs 1C, 3B). The protoconch pattern in *S. chambersae* is broadly similar to that of *Biomphalopa recava* (Hedley, 1912) in that it is pitted cancellate. However, *B. recava* has a pitted cancellate sculpture with narrow spiral cords and wider radial ribbing compared to that of *S. chambersae* which has much broader spiral cords (Figs 1B, C). The orange-brown coloured shell with slightly sunken spire, open cup-shaped umbilicus and nautiloid coiling of *S. chambersae* also differs from that of *B. recava* which has a cream coloured shell with reddish-brown flammulations and a strongly biconcave, multi-whorled shell with a wide cup-shaped umbilicus. *S. chambersae* has a long epiphallus entering the pear-shaped penis laterally (Fig. 4A) similar to that of *B. recava* which has a the tubular penis and much shorter epiphallus (Stanisic 2010: Fig. 58b). *S. chambersae* is restricted to the moist rainforests

of Eungella NP in the Clarke Ra. With an annual rainfall of around 2300 mm (Bureau of Meteorology 2017), the Eungella Plateau rises to an altitude of 1259 m at Mt Dalrymple. The species has been collected from lower altitudes at Broken R. (alt. 470 m) and Finch Hatton Gorge (alt. 250 m) to the higher slopes of Mt Dalrymple.

Radiolaropa gen. nov.

Type species. *Gyrocochlea danieli* Stanisic, 2010-herein designated.

Etymology. From the Latin *radiolus* = rays referring to the 'dominant radial ribs on the protoconch.'

Diagnosis. Shell tiny, light brown, discoidal, nautiliform with a slightly sunken spire; whorls rounded, last weakly descending; protoconch early spiral with prominent, curved radial ribs and very low spiral cords (Fig. 1D); teleoconch with very crowded, bladed radial ribs (c. 150 on last whorl), microsculpture of prominent microradial threads over very low microspiral cords forming weak buttresses at their intersection with the microradials; umbilicus wide, V-shaped.

Remarks. *Radiolaropa* gen. nov. differs from both *Whitcochlea* gen. nov. and *Stanisicaropa* gen. nov. by the combination of smaller size, having more prominent radial ribs on the early spiral protoconch and in having a much more densely ribbed teleoconch. *Radiolaropa* differs from *Gyrocochlea* s.s. by having an early spiral protoconch (Fig. 1D) which contrasts with the fine, beaded cancellate pattern seen in the latter (Fig. 1A). This difference is equivalent to the differences between *Gyrocochlea* s.s. and some of the new genera described by Shea *et al.* (2012) and is herein considered sufficient to justify the description of a new genus for '*Gyrocochlea*' *danieli* Stanisic, 2010 with the addition of *R. eungella* sp. nov. Further *Radiolaropa* species may be present in the Rockhampton-Byfield area, SEQ (Stanisic, pers. comm).

***Radiolaropa danieli* (Stanisic, 2010) comb. nov.**
(Figs 1D, 3I, 7A-B, 10, Table 1)

Gyrocochlea danieli Stanisic, 2010 (in Stanisic *et al.* 2010, sp. 294).

Material examined. Holotype. QMMO35807, 1RC, upper reaches of Endeavour Ck, Clarke Ra., W of Mackay, 21°15'30"S, 148°37'30"E, rainforest, under logs, coll. J. Stanisic, 20.v.1990.

Paratypes. QMMO11745, 4SC, same data as holotype.

Other material. QMMO85340, 1RC, Cherry Tree Ck, 1.2 km off Pinnacle Station Road, MEQ, vine forest, 21° 12' S, 148° 42' E, under rocks and logs, coll. J. Stanisic, L. Holcroft, 17.xi.2016.

Diagnosis. Shell tiny, light brown, discoidal, nautiliform with a slightly sunken spire; whorls rounded, last weakly descending; protoconch early spiral with very low spiral cords and prominent, radial ribs (Fig. 1D); teleoconch with very crowded, bladed radial ribs (c. 150 on last whorl), microsculpture of prominent microradial threads over very low microspiral cords forming weak buttresses at their intersection with the microradials; umbilicus wide, V-shaped.

Description. Shell tiny, orange-brown with darker radial bands, discoidal, nautiliform with a slightly sunken spire; whorls 4.125; sutures moderately impressed; diameter of shell 2.92 mm, height 1.62 mm; H/D 0.5-0.66 (mean 0.61). Protoconch flat, 1.5 whorls, diameter 490 µm, early spiral with low spiral cords and widely spaced prominent, radial ribs on the latter part of the protoconch; teleoconch with crowded radial ribs, 67-94 (mean 79) on the first whorl; microsculpture of microradial threads and very low spiral cords buttressing against the radial threads; aperture ovately lunate; umbilicus wide, V-shaped, diameter 1.07-1.56 mm (mean 1.26mm), D/U 1.84-3.46 (mean 2.57). Based on 3 measured adult specimens.

Distribution and habitat. Endeavour Ck and Cherry Tree Ck, Clarke Ra., MEQ; restricted to riparian rainforest environments of Endeavour Ck and Cherry Tree Ck south of Finch Hatton, living under logs and rocks.

Remarks. *Radiolaropa danieli* (Stanisic 2010) comb. nov. is distinguished by the combination of strong bladed, radial ribs on the early spiral

protoconch which run over the spirals and more intense teleoconch ribbing (Figs 1D, 3C). A specimen from Bell's Gap (QMMO11745) was originally considered conspecific with *R. danieli* by Stanisic *et al.* (2010) but is shown to be a different species below. *R. danieli* is found at Endeavour Ck and Cherry Tree Ck in the lower altitudes of the Crediton SF, MEQ (alt. 575 m). Both creeks are relatively inaccessible and further collecting of the surrounding habitats is needed to establish the full extent of the species' range.

***Radiolaropa eungella* sp. nov.**
(Figs 1E, 3D, 7C-D, 10, Table 1)

Etymology. Named for the Eungella Dam area, the type locality.

Preferred common name. Eungella Dam Pinwheel Snail

Material examined. Holotype. QMMO36099, 1RC, Eungella Dam, c. 1.5 km E on road to Eungella, W Mackay, 21°10'S, 148°23'E, coll. J. Stanisic, 21.v.1990. Diameter 2.95 mm, height 1.56 mm, H/D 0.53, D/U 2.4, number of whorls 4.125.

Paratype. QMMO85343, 1RC, Hazelwood Ck, Lizzie Ck Rd at pipeline Xing, MEQ, sevt, 20° 10' S, 148° 22' E, under rocks, coll. J. Stanisic, L. Holcroft, 18.xi.2016.

Other Material. AMSC154898, 1RC, Homevale, N of Nebo, 21° 24' S, 148° 33' E, 440m, sevt, coll. J. Burch, W. Ponder, P. Colman, 5.v.1975.

Diagnosis. Shell tiny, white, discoidal, nautiliform with a slightly sunken spire; protoconch early spiral with initial low, broad spiral cords rising over strong, bold radial ribs after the first whorl; teleoconch with very crowded, moderately thin, bladed radial ribs recurved towards the suture at the apical end and microsculpture of prominent microradial threads and low microspiral cords forming buttresses at their intersection with the microradials; umbilicus V-shaped.

Description. Shell tiny, white, discoidal, nautiliform with a slightly sunken spire; whorls 3.875-4.125 (mean 4); sutures moderately impressed; diameter of shell 2.95-3.11 mm (mean 3.03 mm), height 1.56-1.64 mm (mean 1.6 mm); H/D 0.53. Protoconch flat, 1.5 whorls, diameter 490 µm, early spiral with initial low,



FIG. 4. Terminal male genitalia. A, *Staniscaropa chambersae* (Stanisic, 2010) comb. nov., QMMO78961. B, *Whitcochlea iuloidea* (Forbes, 1851) comb. nov., QMMO85338. Scale bars = 1 mm.

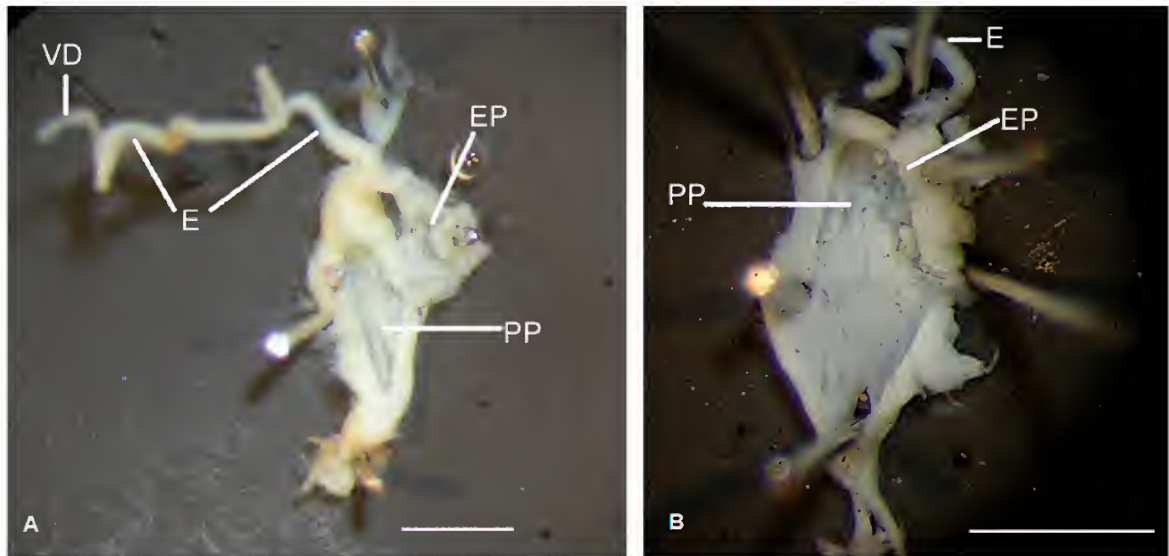


FIG. 5. Internal penial anatomy. A, *Staniscaropa chambersae* (Stanisic, 2010) comb. nov., QMMO78961. B, *Whitcochlea iuloidea* (Forbes, 1851) comb. nov., QMMO85338. Scale bars = 1 mm.



FIG. 6. Dorsal and ventral views of shells. **A-B**, *Biomphalopa recava* (Hedley, 1912), QMMO39878, paratype, Finch Hatton Gorge, MEQ. **C-D**, *Stanisicaropa chambersae* (Stanisic, 2010) comb. nov., QMMO11758, holotype, Eungella, MEQ. Images: Geoff Thompson, QM.

broad spiral cords rising over strong, bold, radial ribs after the first whorl; teleoconch with very crowded, radial ribs 86-95 (mean 91 on the first whorl), prominent microradial threads and low microspiral cords forming buttresses at their intersection with the microradials; aperture ovately lunate; umbilicus V-shaped,

diameter 1.07-1.23 mm (mean 1.15 mm), D/U 2.40-2.92 (mean 2.6). Based on 2 measured adult specimens.

Distribution and habitat. Eungella Dam area, Hazelwood Gorge, Homevale, MEQ; in semi-evergreen vine thicket living under logs and rocks.

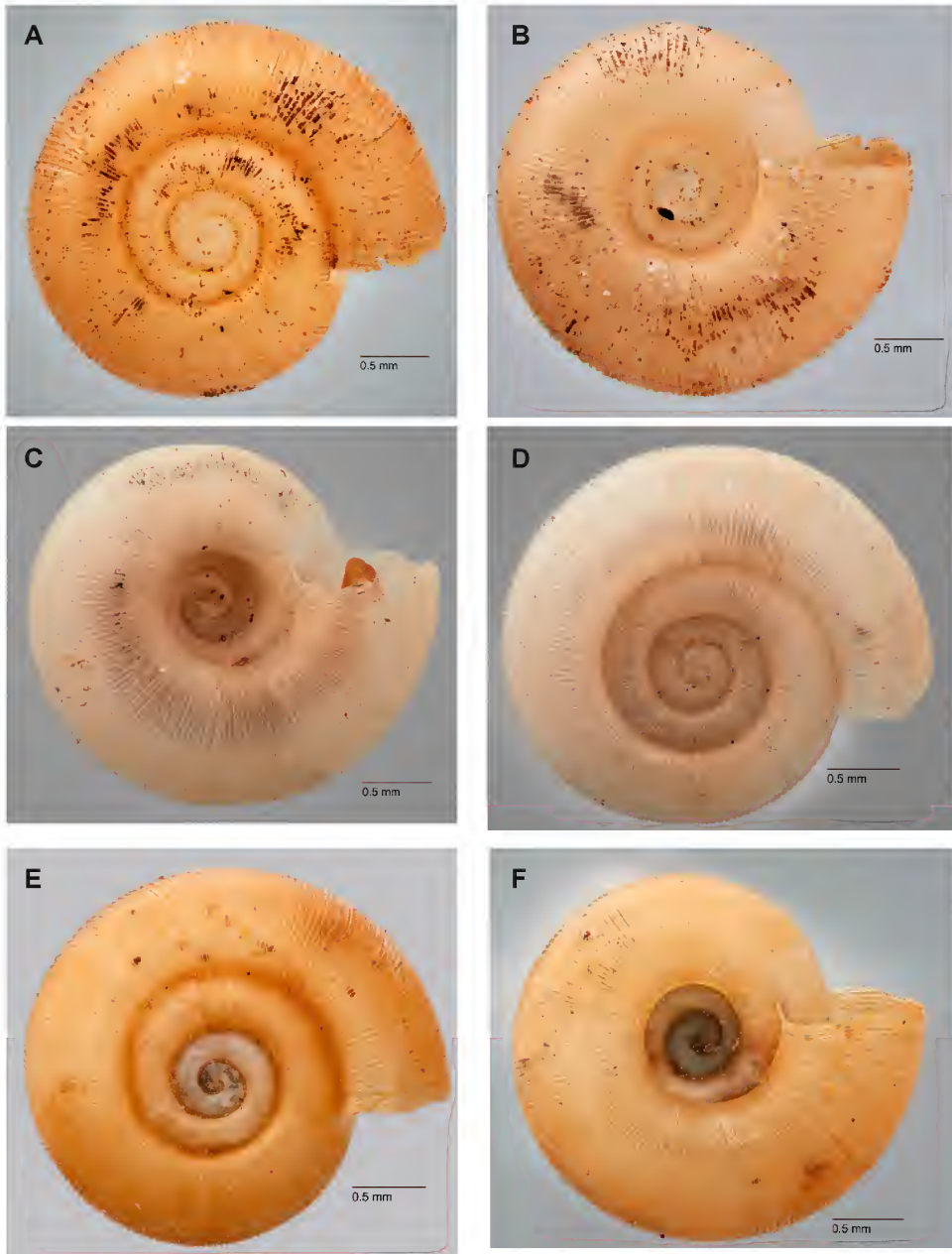


FIG. 7. A-B, *Radiolaropa danieli* (Stanisic, 2010) comb. nov., QMMO35807, holotype. Endeavour Ck, MEQ. C-D, *Radiolaropa eungella* sp. nov., QMMO36099, holotype, Eungella Dam, MEQ. E-F, *Nodularopa samanthae* sp. nov., QMMO77397, holotype, Upper Funnel Ck, MEQ. Images: Geoff Thompson, QM.

Remarks. *Radiolaropa eungella* sp. nov. can be separated from *R. danieli* (Stanisic, 2010) comb. nov. by the white shell colour, lower H/D ratio, finer teleoconch ribbing and smaller umbilical width. *R. eungella* with the preferred habitat of semi-evergreen vine thickets of Eungella Dam, Hazelwood Gorge and Homevale, MEQ, shares similar shell dimensions and protoconch sculpture to those of *Nodularopa samanthae* sp. nov. from moister rainforests of the eastern escarpments of the Connors Ra. closer to the MEQ coast, but can be distinguished by the combination of lighter shell colour and lack of nodulose protoconch and teleoconch sculpture.

Nodularopa gen. nov.

Type species. *Nodularopa samanthae* sp. nov.- herein designated.

Etymology. From the Latin *nodulus* = a small, knot like protuberance, relating to the nodular appearance of the radial ribs on both the protoconch and teleoconch; and a contraction of *Charopa*.

Diagnosis. Shell tiny, white to brown, discoidal, nautiliform with a slightly sunken spire; protoconch early spiral with initial low, broad spiral cords rising over strong, bold radial ribs forming nodules at their intersection; teleoconch with crowded radial ribs crossed by low microspiral cords forming nodules at their intersection; microsculpture of prominent microspiral cords and thin microradial threads forming beads or nodules at their intersection; umbilicus wide, V-shaped.

Remarks. *Nodularopa* gen. nov. is distinguished from other MEQ *Gyrocochlea*-grade genera by the combination of a nodulose early spiral protoconch and nodulose radial ribbing on the teleoconch. Additional *Gyrocochlea*-grade species possessing similar nodulose shell sculpture exist in the Calliope-Rockhampton area, SEQ but require further study in order to confirm their inclusion in *Nodularopa* (Stanisic, pers. comm.).

Nodularopa samanthae sp. nov. (Figs 1F, 3E, 7E-F, 12, Table 1)

Gyrocochlea danieli Stanisic 2010 (in Stanisic *et al.* 2010) [partim]

Etymology. Named for the author's daughter, Samantha.

Preferred common name. Nodular Pinwheel Snail

Material examined. Holotype. QMMO77397, 1RC, Sarina, SW at upper Funnel Ck, 21°34'S, 149°12'E, 200-450m, coll. QM party, 16.xi.1992. Diameter 2.79 mm, height 1.64 mm, H/D 0.59, D/U 2.62, number of whorls 4.

Other material. QMMO11745, 1RC; QMMO13081, 3RC, Bell's Gap, Sarina Ra., c. 15km S Sarina on Bruce Highway, 21°31'S, 149°07'E, coll. J. Stanisic, 7.vii.1982.

Diagnosis. As for genus.

Description. Shell tiny, brown, discoidal, nautiliform with a slightly sunken spire; whorls 4-4.25 (mean 4.125); sutures moderately impressed; diameter of shell 2.79-3.61 mm (mean 3.2 mm), height 1.64-2.05 mm (mean 1.84 mm); H/D 0.57-0.59 (mean 0.58). Protoconch flat, 1.5 whorls, diameter 490 µm, early spiral with initial low, broad spiral cords rising over strong, bold, radial ribs after 1 whorl creating nodules at their intersection; teleoconch with very crowded, nodulose radial ribs 60-95 (mean 78) on the first whorl, microsculpture of crowded and prominent microspiral cords and crowded, thin microradial threads forming beads or nodules at their intersection; aperture ovately lunate; umbilicus wide, V-shaped, diameter 1.07-1.31 mm (mean 1.19 mm), D/U 2.62-2.75 (mean 2.68). Based on 2 measured adult specimens.

Distribution and habitat. Funnel Ck and Bell's Gap, Connors Ra., MEQ; in moist humid rainforest living under logs.

Remarks. *Nodularopa samanthae* sp. nov. can be readily distinguished by the nodulose early spiral protoconch sculpture and prominent nodulose teleoconch ribbing (Figs 3F, 4H). The specimens from Funnel Ck were previously undescribed while the specimens from Bell's Gap were originally ascribed to '*Gyrocochlea danieli* Stanisic, 2010 (Stanisic *et al.* 2010) based on gross shell similarity. More detailed study by SEM has shown that there is a marked difference in early the spiral protoconch sculpture between the latter species and *N. samanthae* having closely spaced spiral cords

that form a nodule at the intersection of the radial ribs in the second part of the protoconch unlike that of both *Radiolaropa* gen. nov. species where the weak spiral cords run under the stronger, more prominent radial ribs. This warrants both specific and generic separation.

***Amfractaropa* gen. nov.**

Type species. *Amfractaropa bretti* sp. nov.- herein designated.

Etymology. From the Latin *amfractus* = coil or spiral relating to the protoconch sculptural pattern; and a contraction of *Charopa*.

Diagnosis. Shell tiny, brown, discoidal, nautiliform with a slightly sunken spire; protoconch flat, 1.75 whorls, spiral with broad spiral cords and broad radial ridges only appearing after 1.5 whorls - in a transition to the teleoconch that occupies $\frac{1}{4}$ of a whorl; teleoconch with very crowded radial ribs, microsculpture of prominent microradial threads and numerous, low microspiral cords forming buttresses at their intersection with the microradials, spiral cords rolling over the major ribs, though ribs appearing as blades where the shell has been worn; umbilicus wide V-shaped.

Remarks. *Amfractaropa* gen. nov. can be distinguished from other MEQ *Gyrochochlea*-grade genera by the combination of brown shell colour, spiral protoconch sculpture, a longer than normal protoconch (1.5 whorls), dense radial ribbing on the teleoconch and a wide V-shaped umbilicus. *Amfractaropa* is similar to *Diphyoropa* Hyman & Stanisic, 2005 from SEQ and NSW in having similar shell sculpture and a longer than normal spiral protoconch with the last quarter whorl transitioning into the teleoconch having broad radial ribs. However, *Amfractaropa* can be distinguished from *Diphyoropa* by having a protoconch sculpture of regular spiral cords unlike the bimodal spiral pattern of *Diphyoropa*. Several undescribed species with a similar protoconch sculpture from the SEQ may also belong in *Amfractaropa* (Holcroft, unpub.). The species is found in the rainforest of the Broken R. in the Eungella NP, MEQ.

***Amfractaropa bretti* sp. nov.**
(Figs 2A, 3F, 8A-B, 10, Table 1)

Etymology. Named for the author's son, Brett.

Preferred common name. Broken River Pinwheel Snail

Material examined. **Holotype.** QMMO6376, 1RC, Eungella NP, Broken R, 21°10'S, 148°30'E, 800m, coll., M. Bishop, xi.1976. Diameter 3.2 mm, height 1.64 mm, H/D 0.51, D/U 5.57, number of whorls 4.125.

Paratypes. QMMO11716, 3SC, Eungella NP, Broken R, 21°10'S, 148°30'E, nvf, coll., J. Stanisic, 5.vii.1982.

Other material. QMMO59545, 1SC, Crediton Ck, Eungella NP, 21°11'S, 148°32'E, 850m, coll., M. Bishop, xi.1976.

Diagnosis. As for genus.

Description. Shell tiny, brown, discoidal, nautiliform with a slightly sunken spire; whorls 4; sutures moderately impressed; diameter of shell 2.87-3.52 mm (mean 3.14 mm), height 1.39-1.8 mm (mean 1.61 mm); H/D 0.47-0.54 (mean 0.51). Protoconch flat, 1.75 whorls, diameter 490 μ m, spiral with broad spiral cords, and broad radial ridges only appearing after 1.5 whorls in a transition to the teleoconch; teleoconch with very crowded radial ribs, 83-121 (mean 104) on the first whorl; microsculpture of prominent microradial threads and numerous, low microspiral cords forming buttresses at their intersection with the microradials, spiral cords rolling over the major ribs though ribs appearing as blades where the shell has been worn; aperture ovately lunate; umbilicus wide V-shaped, diameter 0.57-1.07 mm (mean 0.85 mm), D/U 3-5.57 (mean 3.94). Based on 6 measured adult specimens.

Distribution and habitat. Broken R. and catchment area, Eungella NP, MEQ; in moist humid rainforest living under logs.

Remarks. *Amfractaropa bretti* sp. nov. is distinguished among MEQ *Gyrochochlea*-grade charopids by having a spiral protoconch with broad spiral cords (Fig. 3A). However, *Diphyoropa jonesi* Stanisic, 2010 from Goomeri, SEQ and several undescribed species from SEQ (Bunya Mts, Mt Mudlo and Gatton) have a comparable spiral sculpture on a longer than

normal protoconch and similar teleoconch structures (Holcroft, pers. obs.). However, *A. bretti* differs from these southern species by having a larger number of broader spirals on the protoconch especially towards the suture (mean 19). Further investigation of possible links with the SEQ charopids with the similar protoconch architecture is needed to confirm possible relationships. The longer protoconch length of 1.75 whorls separates *A. bretti* from two other MEQ charopid species with spiral protoconchs viz. *Comularopa georginae* sp. nov. and *Sinployea intensa* (Iredale, 1941) (see Stanisic 1990), both of which have the more common protoconch of 1.5 whorls.

Comularopa gen. nov.

Type species. *Comularopa georginae* sp. nov.- herein designated.

Etymology. From the Latin *comula* = dainty; and a contraction of *Charopa*.

Diagnosis. Shell tiny, light brown, discoidal, nautiliform with a slightly sunken spire; protoconch spiral with thin spiral cords; teleoconch with extremely crowded radial ribs, microsculpture of prominent microradial threads and numerous, low microspiral cords forming buttresses at their intersection with the microradials, spiral cords rolling over the major ribs; umbilicus wide V-shaped.

Remarks. *Comularopa* gen. nov. is distinguished from other MEQ Gyrocochlea-grade genera by the combination of light brown shell colour, protoconch sculpture of thin spiral cords, ultra-fine radial ribbing on the teleoconch and a narrow, U-shaped umbilicus. *Comularopa* is similar to *Amfractaropa* gen. nov. in shell sculpture but can be distinguished from the latter by having smaller shell dimensions but most notably, a smaller protoconch diameter (Table 1). The protoconch sculpture of *Comularopa* consists of thin, continuous equally spaced spiral cords running all the way to the teleoconch. As such, there is no transition zone of different microsculpture before the beginning of the teleoconch, in contrast to the case in larger charopids including *Amfractaropa*. Although the genus is currently considered monotypic

additional species of *Comularopa* may occur in the Rockhampton-Byfield area, SEQ (Stanisic, pers. comm.).

Comularopa georginae sp. nov. (Figs 2B, 3G, 8C-D, 10, Table 1)

Etymology. Named for the author's daughter-in-law, Georgina.

Preferred common name. Crediton Creek Pinwheel Snail

Material examined. Holotype. QMMO59546, 1RC, Crediton Ck, Eungella NP, 21°11'S, 148°32'E, 850 m, coll., M. Bishop, xi.1976. Diameter of shell 2.3 mm, height 1.31 mm, H/D 0.57, D/U 3.5, number of whorls 3.875.

Paratypes. QMMO59645, 2RC, same data as holotype.

Description. Shell tiny, light brown, discoidal, nautiliform with a slightly sunken spire; whorls 3.875; sutures moderately impressed; diameter of shell 2.3 mm, height 1.31 mm; H/D 0.57. Protoconch flat, 1.5 whorls, diameter 410 µm, spiral with thin, bladed equidistant spiral cords (mean 13), teleoconch with ultra-fine crowded radial ribs, 132 on the first whorl; microsculpture of prominent microradial threads and numerous, low microspiral cords forming buttresses at their intersection with the microradials, spiral cords rolling over the major ribs; aperture ovately lunate; umbilicus wide V-shaped, diameter 0.66 mm, D/U 3.5. Based on 1 measured adult specimen.

Distribution and habitat. Hitherto known only from Crediton Ck, Eungella NP, MEQ; in moist humid rainforest living under logs.

Remarks. *Comularopa georginae* sp. nov. can immediately distinguished by the spiral protoconch consisting of thin bladed, equidistant spirals (Fig. 3B) and also differentiates the species from the grossly similar *Amfractaropa bretti* sp. nov. which has a spiral protoconch with low, broad spirals. In addition *C. georginae* has a smaller protoconch diameter (consistently larger in *A. bretti*, Table 1) and a lower D/U ratio. While it may seem ambitious to describe a genus and species on a single adult specimen, the distinctive spiral protoconch is thus far unique among eastern Australian *Gyrocochlea*-

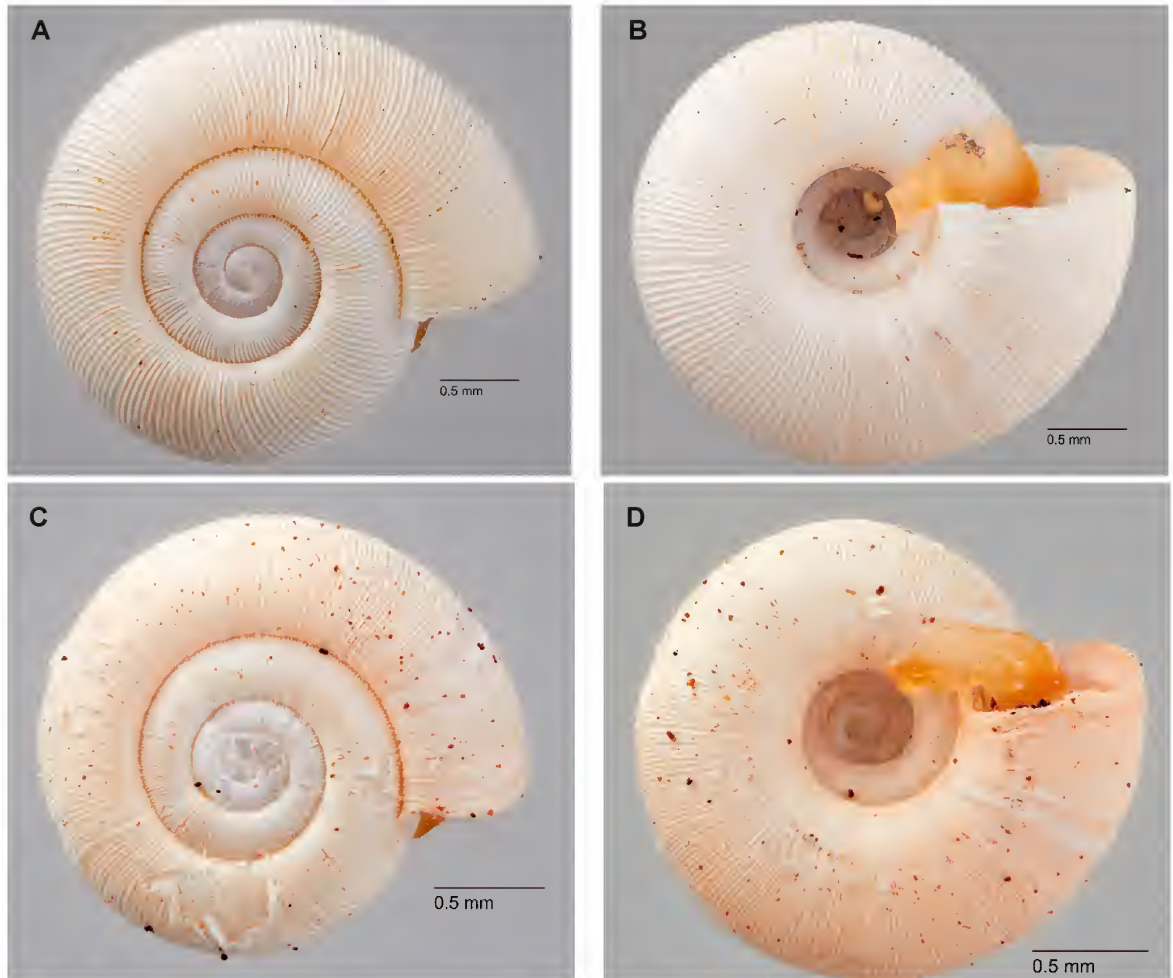


FIG. 8. Dorsal and ventral views of shells. A-B, *Amfractaropa bretti* sp. nov., QMMO6376, holotype, Broken R., MEQ. C-D, *Comularopa georginae* sp. nov., QMMO59546, holotype, Crediton Ck, MEQ. Images: Geoff Thompson, QM.

grade species and is considered justification for such a decision.

Whitcochlea gen. nov.

Type species. *Helix iuloidea* Forbes, 1851-herein designated.

Etymology. From a contraction of Whitsunday and a contraction of *Gyrochochlea*, alluding to the distribution of the species in the Whitsunday biogeographic province and the general similarity to *Gyrochochlea* s.s.

Diagnosis. Shell small, brown, discoidal, nautiliform with a slightly sunken spire;

protoconch superior spiral with numerous, low, broad spiral cords becoming thinner towards the protoconch-teleoconch boundary rising over low curved radial ridges; teleoconch with crowded, moderately thin, bladed radial ribs recurved towards the suture at the apical end and microsculpture of prominent microradial threads and low microspiral cords forming buttresses at their intersection with the microradials; umbilicus wide, cup-shaped; penis tubular with longitudinal pilasters and a long epiphallus entering the penis apically.

Remarks. *Whitcochlea* gen. nov. can be distinguished from other MEQ *Gyrocochlea*-grade genera by the combination of a relatively large-sized, brown shell, superior spiral protoconch sculpture, dense radial ribbing on the teleoconch and a very wide umbilicus. The genus appears to be monotypic and endemic to MEQ.

***Whitcochlea iuloidea* (Forbes, 1851) comb. nov.**
(Figs 2C, 3H, 4B, 5B, 9A-B, 10, Table 1)

Helix iuloidea Forbes, 1851: 379.

Gyrocochlea iuloidea (Forbes). Iredale, 1937: 323; Smith, 1992: 191; Stanisc, 2010 (in Stanisc *et al.* 2010, sp. 296)

Syntypes. NHM1859.3.11.15, 2 specimens (*vide* Smith 1992), Port Molle, MEQ-therein designated.

Taxonomic issues. The syntypes cited in Smith (1992) were not sighted and unable to be located by staff of the NHM, London. Topotypic specimens were collected and used in this study.

Material examined. Long I: QMMO64881, 1SC/1RC; QMMO64807, 4SC/3RC; QMMO74082, 1SC/6RC; QMMO85338, 6SC/7RC. Conway Ra.: QMMO85181, 1RC; QMMO6342, 28RC; JW1449, 2RC; QMMO6340, 13SC; QMMO6341, 2RC; QMMO6343, 1SC; QMMO19928, 7SC; QMMO35366, 3SC; QMMO59185, 1SC; QMMO85110, 16SC; QMMO85124, 1RC; AMSC154888, 6RC; AMSC154889, 1RC; QMMO85334, 8SC/6RC. Riordan Vale: JW1512, 11RC. Airlie Beach: QMMO20143, 4RC/2SC; QMMO35357, 4SC/8RC. Gloucester I: QMMO85186, 1RC; QMMO74108, 1RC. Hamilton I: QMMO85182, 1RC; QMMO65833, 2RC. Peter Faust Dam: QMMO85183, 1RC; QMMO35569, 2SC/5RC. Whitsunday I: QMMO85184, 1RC; QMMO65943, 4RC; QMMO65923, 2SC/2RC. Proserpine R: QMMO85185, 1RC; QMMO39879, 2RC; JW3857, 2RC; QMMO42391, 1RC; QMMO58018, 2SC/1RC; QMMO77414, 3SC; QMMO77418, 1SC; QMMO85107, 1SC. Mt Dryander: QMMO85187, 1RC; QMMO35545, 12SC; JW3433, 8RC; QMMO19981, 15SC/5RC; QMMO35560, 6SC/2RC; QMMO54774, 1RC; QMMO59193, 6SC; QMMO77221, 1SC; QMMO77444, 3SC; AMSC140445, 4RC; AMSC154894, 1RC. Mt Jukes: JW3444, 3RC.

Diagnosis. As for genus.

Description. Shell small, brown, discoidal, nautiliform with a slightly sunken spire; whorls 4-4.75 (mean 4.25); sutures moderately impressed; diameter of shell 3.61- 5.66 mm (mean 4.66 mm), height 1.8-3.11 mm (mean 2.48 mm); H/D 0.33-0.72 (mean 0.53). Protoconch flat, 1.5 whorls, diameter 490-740 μ m (mean 610 μ m), superior spiral with low, broad spiral

bands over weaker radial ribs; teleoconch with crowded radial ribs, 43-66 (mean 48) on the first whorl; microsculpture of microradial threads and very low spiral cords buttressing against the radial threads; aperture ovately lunate; umbilicus wide cup-shaped, diameter 1.39-2.03 mm (mean 1.68 mm), D/U 2.5-3 (mean 2.75). Based on 68 adult specimens.

Terminal male genitalia (Figs 4B, 5B). Vas deferens-epiphallus junction, a ball and socket arrangement; epiphallus long, longer than penis, initially swollen but becoming thinner nearing penis, entering penis apically through a simple pore. Penis tubular with a thin penial sheath; internally with longitudinal pilasters; penial retractor muscle inserting apically on penis head; length 1.43mm. Based on 1 dissected specimen.

Distribution and habitat. Proserpine R. environs, Mt Dryander, Conway Ra., Gloucester I. and the Whitsunday islands, MEQ; in drier araucarian rainforest living under logs and rocks.

Remarks. *Whitcochlea iuloidea* (Forbes, 1851) comb. nov. was described from Port Molle (= Long I.), MEQ, but the syntypes could not be located in the Natural History Museum, London. As a result, the concept of the species adopted here is based on previous records and other material collected since 1980 and in particular, specimens collected on a 2016 field trip to the type locality. *W. iuloidea* has a superior spiral protoconch (Fig. 3C) which differs from all other known MEQ charopids with the exception of *Xenoropa wigtonensis* sp. nov. and can be distinguished from that species by its smaller size, wider teleoconch ribbing and by broader spiral cords on the protoconch. *W. iuloidea* is found in the Whitsunday biogeographic province which includes the araucarian rainforests of the Whitsunday islands, the Conway Ra., Mt Dryander and the riparian rainforest along the Proserpine R. These drier coastal rainforests, which receive an annual average rainfall of 1300 mm (Bureau of Meteorology 2017), harbour this single *Gyrocochlea*-grade species which is characterised by a superior spiral protoconch. Specimens from Long I. and Mt Dryander

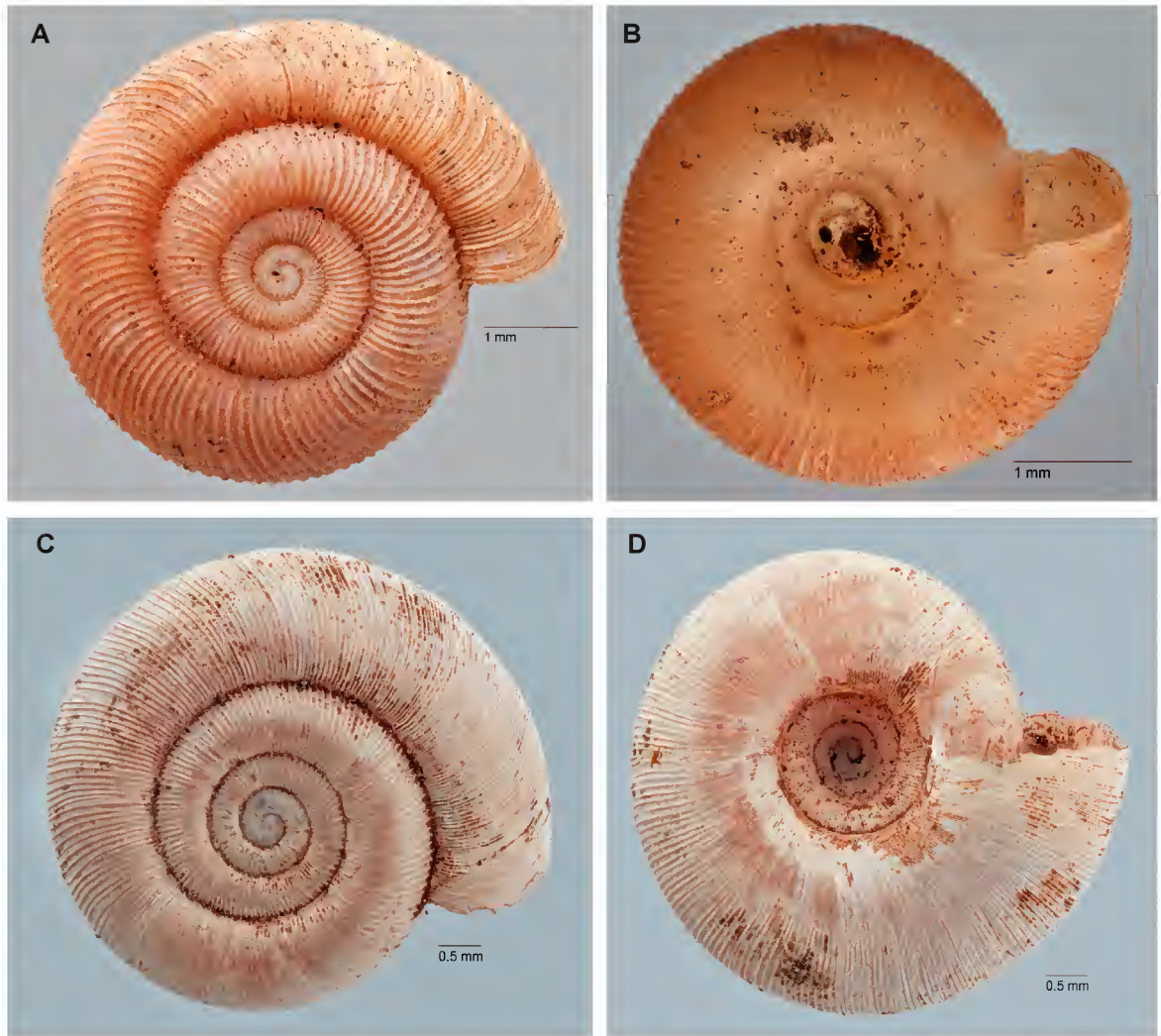


FIG. 9. Dorsal and ventral views of shells. **A-B**, *Whitcochlea iuloidea* (Forbes, 1851) comb. nov., QMMO64881, topotype, Long I, MEQ. **C-D**, *Xenoropa wigtonensis* sp. nov., QMMO85180, holotype, Wigton I, MEQ. Images: Geoff Thompson, QM.

have slightly larger shells than those from the Conway Ra., Mt Jukes and the Proserpine R. (Table 1) although all have a similar shell colour and identical teleoconch sculpture. The specimens group into a single species showing links from the time when sea levels were lower and the land masses connected approximately 15 000 years ago (Willmott 2006).

Xenoropa gen. nov.

Type species. *Xenoropa wigtonensis* -herein designated.

Etymology. From the Ancient Greek *xeno* = foreign relating to granitic xenolithic rock formations found in the South Cumberland Islands; and a contraction of *Charopa*.

Diagnosis. Shell small, orange brown with darker radial bands, discoidal, nautilusform with

a slightly sunken spire; protoconch superior radial with narrow, bladed spiral cords and weaker raised radial ribs, teleoconch with crowded radial ribs and microsculpture of microradial threads and low spiral cords buttressing against the radial threads; aperture ovately lunate; umbilicus wide cup-shaped.

Remarks. *Xenoropa* gen. nov. has a similar superior spiral protoconch sculpture to *Whitcochlea* gen. nov. but is distinguished by having more defined and raised spiral cords and raised radial ribbing on the protoconch as well as by its larger shell dimensions (diameter, height and protoconch diameter, see Table 1). *Xenoropa* gen. nov. is only known from Wigton I., MEQ, however, it may well have a wider distribution on the adjacent mainland.

Xenoropa wigtonensis sp. nov.
(Figs 2D, 3I, 9C-D, 10, Table 1)

Etymology. For Wigton I., the type locality.

Preferred common name. Wigton Island Pinwheel Snail.

Material examined. Holotype. QMMO85180, 1RC, Wigton I., NE of Mackay, 20° 43' 25" S, 149° 27' 36" E, coll. J. Stanisic, T. Carless, 21.viii.2001. Diameter of shell 6.15 mm, height 2.95 mm, H/D 0.48, D/U 3.23, number of whorls 4.375.

Paratype. QMMO70431, 1RC, same data as holotype.

Diagnosis. As for genus.

Description. Shell small, brown, discoidal, nautiliform with a slightly sunken spire; whorls 4.375; sutures moderately impressed; diameter of shell 5.9–6.15 mm (mean 6.02 mm), height 2.79–2.95 mm (mean 2.87 mm); H/D 0.47–0.48 (mean 0.48). Protoconch flat, 1.5 whorls, diameter 740–820 µm (mean 780 µm), superior spiral with narrow, bladed spiral bands over weaker raised radial ribs, teleoconch with crowded radial ribs, 57–68 (mean 68) on the first whorl; microsculpture of microradial threads and very low spiral cords buttressing against the radial threads; aperture ovately lunate; umbilicus wide cup-shaped, diameter 1.97–2.05 mm (mean 2.01 mm), D/U 2.88–3.13 (mean 3). Based on 2 measured adult specimens.

Distribution and habitat. Hitherto known only from Wigton I., MEQ; in araucarian rainforest living under logs.

Remarks. *Xenoropa wigtonensis* sp. nov. is broadly similar to *Whitcochlea iuloidea* (Forbes, 1851) in having a brown shell with similar umbilical width and apertural height and a superior spiral protoconch sculpture (Fig. 2D). However, *X. wigtonensis* is distinguished from *W. iuloidea* by the combination of a larger shell diameter (over 6 mm) and shell height, a larger number of whorls, a larger protoconch diameter and much denser radial ribbing on the teleoconch (mean 52 ribs on the third quarter of body whorl as opposed to an average of 25 on the third quarter of the body whorl of *W. iuloidea*: Table 1). No animal tissue of this species was available for anatomical analysis and the description was made from two worn specimens. The SEM image of the protoconch sculpture was taken through the umbilicus due to damage on the apices of each specimen. Additional material is needed to more fully document the species conchological features.

X. wigtonensis is presently known only from Wigton I. in the south Cumberland Group and not from the Whitsunday Islands. However, further collecting on this and the surrounding islands may extend the range of this species. *W. iuloidea*, first recorded from an off-lying island was subsequently found on the adjacent mainland areas and given the similar geological history of this region, it is quite possible for *X. wigtonensis* or a sister species to be present on the adjacent mainland. However, given that this section of the mainland is part of the Proserpine-Sarina lowlands that have been heavily impacted by clearing for sugar cane farming and cattle grazing, a continental relative in mainland MEQ could be difficult if not impossible to locate. Continental relatives may be present on the mainland further south.

Discussion. *Gyrocochlea* Hedley, 1924 has historically been a convenient generic 'repository' for eastern Australian mainland charopids with prominently ribbed, brown discoidal shells. Shea *et al.* (2012) have shown that *Gyrocochlea* s.s. only applies to a small suite

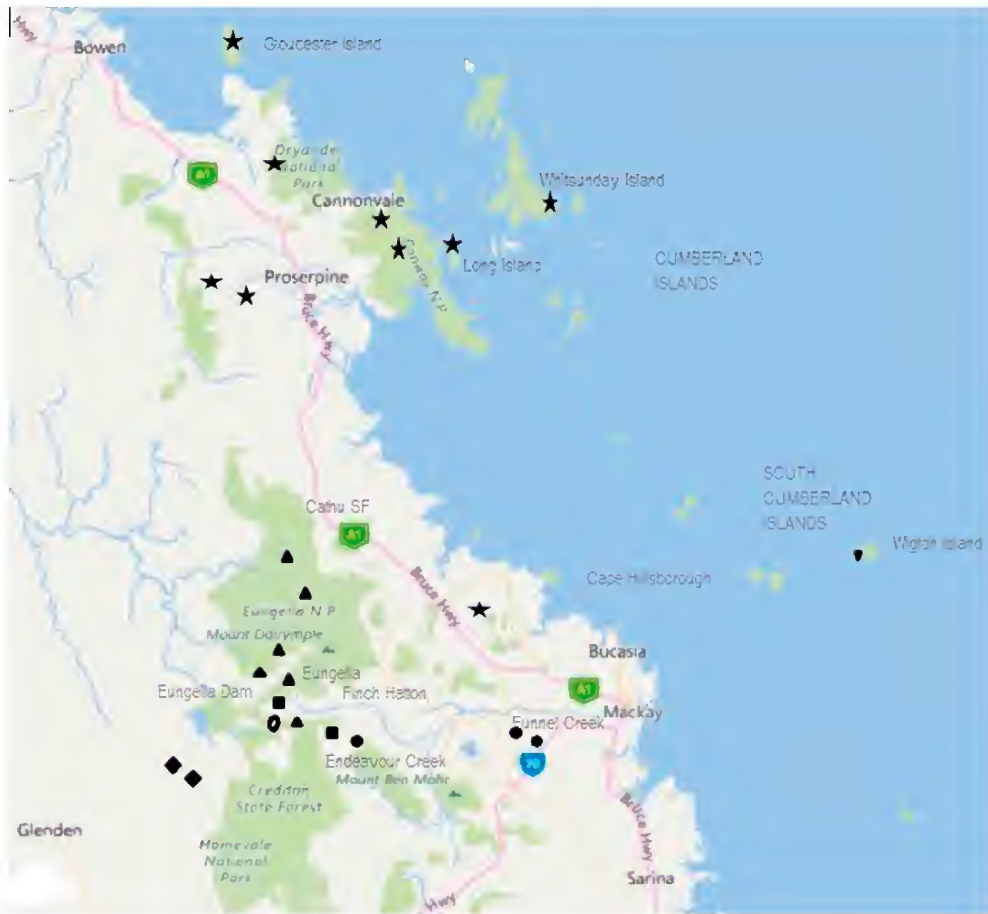


FIG. 10. Map showing localities of MEQ *Gyrochochlea*-grade species. Species are identified by the following symbols: ◆ *Biomphalopa recava* (Hedley, 1912); ▲ *Stanisicaropa chambersae* (Stanisic, 2010) comb. nov.; ● *Radiolaropa danieli* (Stanisic, 2010) comb. nov.; ◆ *Radiolaropa eungella* sp. nov.; ■ *Amfractaropa bretti* sp. nov.; ○ *Comularopa georginae* sp. nov.; ★ *Whitcochlea iuloidea* (Forbes, 1851) comb. nov.; ▼ *Xenoropa wigtonensis* sp. nov.; ⊗ *Nodularopa samanthae* sp. nov.

of species in SEQ and NENSW and that the historical generic concept was polyphyletic and concealed a vast hidden diversity of charopid evolution. Only four species of *Gyrochochlea*-grade charopids have been previously described from MEQ and the present study has shown that a similar scenario exists with these species. The consequent necessary reassignment of these species and the description of new species of *Gyrochochlea*-grade charopids from MEQ in this study has led to the description of seven new genera largely based on differences in protoconch sculpture.

All new genera in this paper can be recognised using protoconch sculpture which differs markedly from the beaded cancellate pattern of true *Gyrochochlea* s.s. (Fig. 1A). Investigations under optical microscopy reveal a predominantly spiral pattern on most protoconchs. Closer examination under SEM (Figs 1, 2) provides further differentiation in the spiral pattern with superior spiral (*Whitcochlea* and *Xenoropa*), spiral (*Amfractaropa* and *Comularopa*), early spiral (*Nodularopa* and *Radiolaropa*) and pitted cancellate (*Stanisicaropa* and *Biomphalopa*) patterns emerging in the protoconch architecture. This reinforces



FIG. 11. MEQ *charopid* habitats. A, Moist montane rainforest of Broken R., Eungella NP, MEQ. B, Drier araucarian rainforest of the Whitsunday Islands, MEQ. C, Semi-arid vine thicket of Hazelwood Gorge near Eungella Dam, MEQ.

Stanisic's view (2016) that all protoconch descriptions need to be completed by analysis of scanning electron micrographs.

Gyrocochlea-grade MEQ charopids are chiefly restricted to montane and surrounding moist rainforest habitats of the Clarke-Connors Ra. and the drier coastal araucarian forests of the Conway Ra., Mt Dryander and nearby Whitsunday islands (Fig. 11). A volcanic hotspot

from 32 million years ago at Cape Hillsborough provides a similar forest ecosystem to that of the Whitsundays and is the exception to this as no *Gyrocochlea*-grade species have been found there to date. The semi-evergreen vine thickets of the Eungella Dam environs and notophyll vine forests in the Funnel Ck-Bell's Gap area also support *Gyrocochlea*-grade species. Land clearing and farming in the Proserpine-Sarina lowlands has restricted charopids to remnant patches of vine thicket but no *Gyrocochlea*-grade species has hitherto been discovered in these habitats.

The importance of the Clarke-Connors Ra. and Whitsunday biogeographic provinces as hotspots of charopid endemism raises questions of their evolutionary relationships. Mid-eastern Queensland is separated from the humid, wet tropics and the dry to moist subtropical forests of SEQ by two dry corridors of open eucalypt forest: the Burdekin-Lynd Gap in the north and the St Lawrence Gap in the south. This has isolated the region into refugial pockets of rainforest (Webb & Tracey 1981; Bryant *et al.* 2016) and probably affected subsequent charopid distribution including that of the *Gyrocochlea*-grade species. The nine species dealt with in this study represent one known genus and seven new genera including the re-assignment of the three previously known '*Gyrocochlea*' species from this area. This indicates a level of charopid diversity previously unknown within the MEQ area. The extralimital relationships of these species have yet to be established but the examination of numerous protoconch micrographs undertaken by the author as part of a related study (Holcroft 2018) strongly suggests that these will chiefly be to species in adjacent bioregions to the south. Detailed investigation of *Gyrocochlea*-grade species, particularly in the Calliope-Rockhampton-Byfield area as well as the off-lying islands of the Cumberland, South Cumberland and Northumberland groups should be a priority for future research. However, relatives of at least one of the *Gyrocochlea*-grade species, *Biomphalopa recava*, do occur in adjacent bioregions but in northern Queensland. This MEQ-NEQ relationship also needs to be re-

examined in the detail outlined herein and by Holcroft (2018).

While this study is focused on *Gyrocochlea*-grade charopids, many non-*Gyrocochlea*-grade MEQ charopids are also endemic to the region and similarly appear related to species in the SEQ and the Wet Tropics (Holcroft unpublished). The north-south geographical patterns of charopid lineages that have been identified in recent charopid research (Shea *et al.* 2012; Holcroft 2018) would suggest that continued research into the Charopidae could contribute significantly to an improved biogeographic understanding of eastern Australia.

Conservation

Snails including the Charopidae, are often overlooked in conservation assessments. With their ability to be responsive to environmental change, these tiny charopids make excellent indicators of terrestrial biodiversity and ecosystem health (Stanisic 1990; Stanisic & Ponder 2004; Shea *et al.* 2012). Their endemism in particular has significant impact for all the environments in which they are found. Concerns are being raised about clearing of rainforests (McAlpine *et al.* 2002) and the impact of controlled burn-offs particularly in the Eungella NP where at the point where this national park is no wider than one kilometre, the gradual encroaching of the land affected by these fires into the pristine rainforest could well have the potential to eradicate entire species of charopid.

While none of the MEQ charopids have received conservation protection under legislation, their preference for humid rainforests and vine thickets indicates that conservation of these areas is crucial for the snails' continued survival. Many of the mainland coastal areas have been cleared for farming and the high levels of endemism of this group display would suggest that some species may have already been lost. Much of the remaining rainforest is now situated in National Parks and State Forests which will protect the diversity of these charopids.

ACKNOWLEDGMENTS

First and foremost, the research presented in this paper could not have been achieved without the constant encouragement and constructive feedback of Dr John Stanisic, an expert in his own right on Charopidae and to whom I owe special thanks. Dr Stanisic also supervised and helped with the dissection of the two MEQ species. I am most grateful to my supervisors, Professor Jane Hughes and Dr Chris Burwell from Griffith University, for their ongoing feedback, support and encouragement. I wish to acknowledge Geoff Thompson of the Digital Imaging Unit, Queensland Museum for providing the high quality colour images of the species studied herein. The comprehensive feedback from the two reviewers made a significant difference and I thank them for their time and recommendations for improvement.

LITERATURE CITED

- Bishop, M.J. 1981. The biogeography and evolution of Australian land snails. In A. Keast (ed.), *Ecological Biogeography of Australia*, pp. 924-954. (W. Junk Publishers: The Hague, Netherlands).
- Bonham, K.J. 2003. *Biogeography of Tasmanian native land snails*. PhD thesis, (University of Tasmania: Tasmania).
- Bryant, L.M. & Krosch, M.T. 2016. Lines in the land: a review of evidence for eastern Australia's major biogeographical barriers to closed forest taxa. *Biological Journal of the Linnean Society* 119: 238-264.
- Bureau of Meteorology. 2017. Climate statistics for Australian locations. Available online at <http://www.bom.gov.au> [Accessed on 1 June 2017.]
- Forbes, E. 1851. On the Mollusca collected by Mr Macgillivray during the voyage of the Rattlesnake. Pp. 360-386 In, Macgillivray, J. (ed.) *Narrative of the Voyage of the H.M.S. Rattlesnake commanded by the late Captain Owen Stanley, during the years 1846-1850.*, Volume 2. (T & W Boone: London).
- Hedley, C. 1912. On some land shells collected in Queensland by Mr. Sidney W. Jackson. *Proceedings of the Linnean Society of New South Wales* 37: 253-270.
1924. Some notes on Australian land shells. *Australian Zoologist* 3: 215-222.
- Holcroft, L. 2017. Protoconchs and possibilities: elucidating the diversity of mid-eastern Queensland pinwheel snails (Eupulmonata:

- Charopidae) using aspects of shell morphology. *The Malacological Society of Australasia Newsletter* **160**, 1-6.
2018. Protoconch sculpture as a taxonomic tool in Australian charopid systematics (Gastropoda: Eupulmonata: Charopidae), *Molluscan Research*, <https://doi.org/10.1080/13235818.2017.1409069>.
- Hyman, I.T. & Stanislac, J. 2005. New charopid landsnails, chiefly from limestone outcrops in eastern New South Wales (Eupulmonata: Charopidae). *Memoirs of the Queensland Museum* **50**: 219-302.
- Iredale, T. 1937a. A basic list of the land Mollusca of Australia. *Australian Zoologist* **8**: 287-333.
- 1937b. An annotated checklist of the land shells of south and central Australia. *The South Australian Naturalist* **18**: 6-56.
- McAlpine, C.A., Fensham, R.J. & Temple-Smith, D.E., 2002. Biodiversity conservation and vegetation clearing in Queensland: principles and thresholds. *The Rangeland Journal* **24**: 36-55 <https://doi.org/10.1071/RJ02002>.
- Shea, M., Colgan, D. & Stanislac, J. 2012. Systematics of the landsnail genus *Gyrocochlea* and relatives (Mollusca: Charopidae). *Zootaxa* **3585**: 1-109.
- Smith, B.J. 1992. Non-marine Mollusca. In Houston, W.W.K. (ed.) *Zoological Catalogue of Australia*. (Australian Government Publishing Service: Canberra). Vol. 8 xii 408 pp.
- Smith, B.J. & Kershaw, R.C. 1979. *Field guide to the non-marine molluscs of south eastern Australia*. (Australian National University Press: Canberra) 285pp.
- Solem, A. 1983. *Endodontoid land snails from Pacific Islands (Mollusca: Pulmonata: Sigmurethra). Part II. Families Punctidae and Charopidae, Zoogeography*. (Field Museum: Chicago).
- Stanislac, J. 1990. Systematics and biogeography of eastern Australian Charopidae (Mollusca: Pulmonata) from sub-tropical rainforests. *Memoirs of the Queensland Museum* **30**: 1-241.
1998. Family Charopidae. Pp. 1097-1099 in Beesley, P. L., Ross, G. J. B. & Wells, A. (eds) *Mollusca: The Southern Synthesis. Fauna of Australia*. Vol. 5. Part B viii, 565-1234pp (CSIRO Publishing: Melbourne).
2016. Two new species of Pinwheel Snail from Queensland and a redescription and generic reassignment of *Gyrocochlea myora* Stanislac, 2010 (Gastropod: Eupulmonata: Charopidae), *Memoirs of the Queensland Museum-Nature* **60**: 1-12.
- Stanislac, J. & Ponder, W.F. 2004. Forest snails in eastern Australia: one aspect of the other 99%. Pp. 127-149 in D. Lunney (ed.) *Conservation of Australia's Forest Fauna*. (Royal Zoological Society of New South Wales: Mosman) <https://doi.org/10.7882/FS.2004.011>.
- Stanislac, J., Shea, M., Potter, D. & Griffiths, O. 2010. *Australian Land Snails Volume 1: A Field Guide to Eastern Australian Species*. (Bioculture Press: Mauritius) 596pp.
- Stanislac, J., Shea, M., Potter, D. & Griffiths, O. 2017. *Australian Land Snails Volume 2: A Field Guide to southern, central and western species*. (Bioculture Press: Mauritius) 594pp.
- Van Bruggen, A.C. 1980. Gondwanaland connections in the terrestrial molluscs of Africa and Australia. *Journal of the Malacological Society of Australia* **4**: 215-222.
- Webb, L. J. & Tracy, J.G. 1981. Rainforests: patterns and change, In, A. Keast (ed.), *Ecological Biogeography of Australia*, pp. 606-694. (W. Junk Publishers: The Hague, Netherlands) https://doi.org/10.1007/978-94-009-8629-9_22.
- Willmott, W. F. 2006. *Rocks and landscapes of the national parks of central Queensland*, (Geological Society of Australia, Queensland Division: Brisbane).

APPENDIX 1. Specimens included in SEM analysis and anatomical dissection

Taxa	Registration number	SEM images taken	Anatomical dissection
<i>Amfractaropa bretti</i>	QMMO11716	✓	
<i>Biomphalopa recava</i>	QMMO39878	✓	
	QMMO85117	✓	
<i>Comularopa georginae</i>	QMMO59546	✓	
<i>Gyrocochlea paucilamellata</i>	QMMO16546	✓	
<i>Gyrocochlea vinitincta</i>	AMSC139752	✓	
<i>Radiolaropa eungella</i>	QMMO36099	✓	
	QMMO95343	✓	
<i>Nodularopa samanthae</i>	QMMO13081	✓	
	QMMO77397	✓	
<i>Radiolaropa danieli</i>	QMMO11745	✓	
<i>Stanisicaropa chambersae</i>	QMMO78961	✓	✓
	QMMO35619	✓	
	QMMO85097	✓	
	QMMO85093	✓	
<i>Whitcochlea iuloidea</i>	QMMO85338	✓	✓
	QMMO85334	✓	
	QMMO85183	✓	
	QMMO74108	✓	
	QMMO65943	✓	
	QMMO65833	✓	
	QMMO64807	✓	
	QMMO59193	✓	
	QMMO39879	✓	
	QMMO6342	✓	
	JW3444	✓	
<i>Xenoropa wigtonensis</i>	QMMO85180	✓	
	QMMO70431	✓	

APPENDIX 2. Measurements of MEQ *Gyrocochlea*-grade species

Taxon	Reg #	D	H	U	AH	AW	PD	WWB	T1	H/D	D/U	# Whorls	
<i>Stanisicaropa chambersae</i>	QMMO13456	5.41	2.87	1.80	1.89	1.56	0.49	20.00	52.00	0.53	3.00	4.000	
	QMMO11758	4.92	2.79	1.64	2.13	1.72	0.66	23.00	51.00	0.57	3.00	4.500	
	QMMO85079	4.75	2.46	1.31	2.05	1.56	0.66	22.00	61.00	0.52	3.63	4.000	
	QMMO35619	5.49	2.95	1.48	2.38	1.89	0.49	19.00	50.00	0.54	3.72	4.125	
	QMMO13071	5.33	2.95	1.97	2.38	1.64	0.49	17.00	57.00	0.55	2.71	4.250	
	QMMO78961	4.92	2.62	1.56	2.05	1.72	0.49	17.00	51.00	0.53	3.16	4.125	
	QMMO78961	4.43	2.70	1.72	1.97	1.39	0.49	17.00	49.00	0.61	2.57	4.125	
	QMMO78961	5.57	2.87	1.80	2.05	1.80	0.41	21.00	57.00	0.51	3.09	4.125	
	QMMO78961	4.92	2.79	1.64	1.97	1.72	0.49	20.00	52.00	0.57	3.00	4.375	
	QMMO78961	5.49	3.03	1.80	2.05	1.56	0.66	21.00	55.00	0.55	3.05	4.500	
	QMMO78961	5.08	2.95	1.72	2.38	1.72	0.66	22.00	60.00	0.58	2.95	4.375	
	QMMO11758	4.92	2.62	1.56	2.05	1.56	0.57	22.00	42.00	0.53	3.16	4.250	
	QMMO11714	4.26	2.54	1.39	2.05	1.56	0.66	17.00	55.00	0.60	3.06	4.000	
MEAN: <i>Stanisicaropa chambersae</i>	13 adult specimens	5.04	2.78	1.65	2.11	1.65	0.55	19.85	53.23	0.55	3.08	4.212	
<i>Radiolaropa danieli</i>	QMMO35807	2.87	1.89	1.56	1.48	0.98	0.49	42.00	76.00	0.66	1.84	3.750	
	QMMO35807	2.87	1.80	1.15	1.56	1.31	0.49	42.00	85.00	0.63	2.50	4.000	
	QMMO85340	3.69	2.05	1.07	1.64	1.31	0.49	46.00	67.00	0.56	3.46	4.125	
MEAN: <i>Radiolaropa danieli</i>	3 adult specimens	3.14	1.91	1.26	1.56	1.20	0.49	43.33	76.00	0.61	2.60	3.96	
<i>Radiolaropa eungella</i>	QMMO85343	3.11	1.64	1.07	1.48	1.07	0.49	38.00	86.00	0.53	2.92	3.875	
	QMMO36099	2.95	1.56	1.23	1.23	0.98	0.49	39.00	95.00	0.53	2.40	4.125	
MEAN: <i>Radiolaropa eungella</i>	2 adult specimens	3.03	1.60	1.15	1.35	1.02	0.49	38.50	90.50	0.53	2.66	4.00	
<i>Whitcochlea iulioidea</i> (Long I)	QMMO64807	5.57	2.54	2.05	2.21	1.80	0.57	24.00	54.00	0.46	2.72	4.750	
	QMMO64807	5.16	2.30	2.05	2.13	1.39	0.66	21.00	53.00	0.44	2.52	4.500	
	QMMO64881	5.66	1.89	1.89	2.13	1.72	0.57	30.00	49.00	0.33	3.00	4.500	
	QMMO74082	5.66	2.46	2.13	2.05	1.56	0.66	24.00	55.00	0.43	2.65	4.250	
	QMMO74082	5.41	2.62	2.05	2.05	1.56	0.66	25.00	53.00	0.48	2.64	4.500	
	QMMO74082	5.41	2.62	2.13	2.05	1.31	0.74	26.00	53.00	0.48	2.54	4.250	
	QMMO85338	5.49	2.95	1.89	2.05	1.97	0.74	26.00	44.00	0.54	2.91	4.625	
	QMMO85338	4.84	2.38	1.72	1.72	0.90	0.66	22.00	51.00	0.49	2.81	4.625	
	QMMO85338	5.00	2.38	1.80	2.13	1.97	0.66	19.00	52.00	0.48	2.77	4.000	
	QMMO85338	5.25	1.80	1.97	1.72	1.48	0.66	23.00	48.00	0.34	2.67	4.500	
	QMMO85338	5.33	2.62	2.13	2.05	1.48	0.66	24.00	53.00	0.49	2.50	4.500	
	QMMO73834	5.57	3.11	2.05	2.21	1.64	0.57	26.00	51.00	0.56	2.72	4.750	
	QMMO85338	4.92	2.79	1.80	1.97	1.48	0.57	24.00	48.00	0.53	2.73	4.250	
	<i>Whitcochlea iulioidea</i>	QMMO6342	4.84	2.70	1.72	2.05	1.64	0.57	25.00	51.00	0.56	2.81	4.250
	(Conway Range)	QMMO6342	4.67	2.46	1.56	2.05	1.64	0.49	27.00	51.00	0.53	3.00	4.375
		QMMO6342	4.51	2.21	1.64	2.13	1.56	0.49	27.00	52.00	0.49	2.75	4.250
QMMO6342		4.51	2.46	1.48	2.05	1.31	0.57	28.00	52.00	0.55	3.06	4.125	
QMMO6342		4.10	2.13	1.56	1.97	1.39	0.49	27.00	59.00	0.52	2.63	4.000	
QMMO6342		4.26	2.30	1.39	2.05	1.48	0.49	27.00	55.00	0.54	3.06	4.250	
QMMO6342		4.34	2.46	1.39	1.97	1.56	0.49	22.00	60.00	0.57	3.12	4.250	

continued...

Gyrochochlea-grade Charopidae (Eupulmonata: Charopidae)

Taxon	Reg #	D	H	U	AH	AW	PD	WWB	T1	H/D	D/U	# Whorls
	QMMO6342	3.77	2.30	1.48	1.97	1.39	0.49	22.00	60.00	0.61	2.56	4.000
	QMMO6342	3.85	2.13	1.48	1.89	1.31	0.49	22.00	46.00	0.55	2.61	4.000
	JW1449	3.85	2.54	1.64	1.97	1.56	0.41	32.00	66.00	0.66	2.35	4.125
	QMMO19928	3.77	2.70	1.56	1.97	1.72	0.57	30.00	57.00	0.72	2.42	4.375
	QMMO20143	3.61	2.13	1.64	1.72	1.23	0.57	30.00	62.00	0.59	2.20	4.250
	QMMO6341	4.10	2.38	1.64	1.72	1.31	0.49	24.00	61.00	0.58	2.50	4.250
	QMMO6341	4.51	2.46	1.64	1.97	1.64	0.57	29.00	54.00	0.55	2.75	4.375
	QMMO85124	4.43	2.21	1.39	1.80	1.56	0.57	25.00	59.00	0.50	3.18	4.375
	QMMO35357	4.92	2.79	1.64	1.72	1.39	0.57	33.00	59.00	0.57	3.00	4.375
	QMMO35357	4.84	2.46	1.56	2.05	1.56	0.57	26.00	59.00	0.51	3.11	4.250
	JW1512	4.51	2.38	1.80	1.97	1.64	0.57	25.00	49.00	0.53	2.50	4.500
	JW1512	4.84	2.46	2.13	1.97	1.56	0.66	23.00	48.00	0.51	2.27	4.000
	JW1512	4.18	2.13	1.64	1.97	1.56	0.57	23.00	45.00	0.51	2.55	4.250
	JW1512	4.26	2.30	1.56	1.64	1.48	0.57	24.00	50.00	0.54	2.74	4.250
	QMMO35357	4.18	2.21	1.39	1.72	1.15	0.57	21.00	59.00	0.53	3.00	4.250
<i>Whitcochlea iuloidea</i>	QMMO85186	4.51	2.62	1.64	1.89	1.56	0.57	25.00	46.00	0.58	2.75	4.375
(Gloucester Island)	QMMO74108	4.43	2.05	1.56	2.05	1.80	0.57	26.00	45.00	0.46	2.84	4.000
<i>Whitcochlea iuloidea</i>	QMMO65833	3.93	2.46	1.56	1.97	1.23	0.66	33.00	51.00	0.63	2.53	4.125
(Hamilton Island)	QMMO85182	4.51	2.46	1.64	1.80	1.48	0.57	30.00	57.00	0.55	2.75	4.250
<i>Whitcochlea iuloidea</i>	QMMO85183	4.67	2.46	1.64	1.97	1.48	0.57	24.00	51.00	0.53	2.85	4.375
(Peter Faust Dam)	QMMO35569	5.00	2.87	1.64	1.89	1.23	0.82	22.00		0.57	3.05	4.125
	QMMO35569	4.84	2.70	1.64	1.80	1.48	0.66	23.00		0.56	2.95	4.250
<i>Whitcochlea iuloidea</i>	QMMO65943	5.00	2.62	1.64	2.05	1.64	0.66	37.00	53.00	0.52	3.05	4.250
(Whitsunday Is)	QMMO85184	4.10	2.21	1.48	1.89	1.48	0.57	30.00	51.00	0.54	2.78	4.000
	QMMO65943	4.26	2.70	1.48	2.05	1.64	0.49	31.00	56.00	0.63	2.89	4.125
	QMMO65923	4.84	2.62	1.64	1.80	1.64	0.66	36.00	52.00	0.54	2.95	4.125
	QMMO65923	4.51	2.38	1.48	1.80	1.39	0.66	35.00	52.00	0.53	3.06	4.125
<i>Whitcochlea iuloidea</i>	JW3857	4.92	2.70	1.72	2.13	1.80	0.74	23.00	51.00	0.55	2.86	4.125
(Proserpine R)	JW3857	4.34	2.46	1.56	1.89	1.56	0.57	25.00	53.00	0.57	2.79	4.125
	QMMO85185	4.75	2.46	1.56	1.64	1.31	0.57	21.00	52.00	0.52	3.05	4.250
<i>Whitcochlea iuloidea</i>	QMMO35560	5.41	3.03	1.80	2.21	2.05	0.57	27.00	45.00	0.56	3.00	4.500
(Mt Dryander)	QMMO35560	4.92	2.70	1.48	2.05	1.80	0.57	26.00	46.00	0.55	3.33	4.250
	AMSC140445	4.75	2.62	1.97	2.13	1.48	0.57	22.00	50.00	0.55	2.42	4.250
	AMSC140445	4.59	2.38	1.80	2.05	1.56	0.57	21.00	49.00	0.52	2.55	4.250
	AMSC140445	4.92	2.54	2.05	2.05	1.72	0.74	19.00	53.00	0.52	2.40	4.000
	AMSC140445	4.43	2.21	1.80	1.97	1.64	0.49	19.00	52.00	0.50	2.45	4.250
	JW3857	5.33	2.87	1.64	2.13	1.80	0.74	26.00	45.00	0.54	3.25	4.500
	JW3857	5.33	2.87	1.89	2.13	1.80	0.57	31.00	49.00	0.54	2.83	4.675
	JW3857	5.33	3.03	1.80	2.21	1.89	0.66	23.00	49.00	0.57	2.95	4.675
	JW3857	4.84	2.79	1.80	2.13	1.97	0.66	22.00	48.00	0.58	2.68	4.375
	JW3857	4.67	2.62	1.64	1.97	1.56	0.57	24.00	46.00	0.56	2.85	4.375
	JW3857	4.84	2.70	1.64	2.05	1.89	0.57	22.00	51.00	0.56	2.95	4.500
	JW3857	4.92	2.46	1.48	2.05	1.39	0.57	26.00	50.00	0.50	3.33	4.500
	JW3857	4.84	2.54	1.56	1.97	1.72	0.74	26.00	43.00	0.53	3.11	4.500
	JW3857	4.92	2.70	1.64	2.05	1.80	0.57	27.00	52.00	0.55	3.00	4.500
<i>Whitcochlea iuloidea</i>	JW3444	5.41	2.87	2.05	2.05	1.72	0.74	27.00	45.00	0.53	2.64	4.250

continued...

Holcroft, L.

Taxon	Reg #	D	H	U	AH	AW	PD	WWB	T1	H/D	D/U	# Whorls
(Mt Jukes)	JW3444	5.00	2.79	1.64	2.30	1.39	0.57	26.00	51.00	0.56	3.05	4.500
	JW3444	4.92	2.62	1.80	2.30	1.72	0.66	0.00	0.00	0.53	2.73	4.375
MEAN: <i>Whitcochlea</i> <i>iuloides</i>	68 adult specimens	4.71	2.54	1.64	1.97	1.55	0.61	25.57	44.63	0.55	2.83	4.24
<i>Xenoropa</i> <i>wigtonensis</i>	QMMO70431	5.90	2.79	2.05	1.80	2.30	0.82	49.00	68.00	0.47	2.88	4.375
	QMMO85180	6.15	2.95	1.97	2.38	1.72	0.74	54.00	67.00	0.48	3.13	4.375
MEAN: <i>Xenoropa</i> <i>wigtonensis</i>	2 adult specimens	6.02	2.87	2.01	2.09	2.01	0.78	51.50	67.50	0.48	3.00	4.375
<i>Comularopa</i> <i>georginae</i>	QMMO59546	2.30	1.31	0.66	0.90	0.66	0.41	66.00	132.00	0.57	3.50	3.875
MEAN: <i>Comularopa</i> <i>georginae</i>	1 adult specimen	2.30	1.31	0.66	0.90	0.66	0.41	66.00	132.00	0.57	3.50	3.875
<i>Nodularopa</i> <i>samanthae</i>	QMMO77397	2.79	1.64	1.07	1.39	1.15	0.49	42.00	95.00	0.59	2.62	4.000
	QMMO11745 QMMO13081	3.61	2.05	1.31	2.05	1.64	0.49	44.00	60.00	0.57	2.75	4.240
MEAN: <i>Nodularopa</i> <i>samanthae</i>	3 adult specimens	3.20	1.84	1.19	1.72	1.39	0.49	43.00	77.50	0.58	2.68	4.12
<i>Biomphalopa</i> <i>recava</i>	QMMO11749	3.28	1.80	1.48	1.48	0.74	0.49	26.00	44.00	0.55	2.22	4.250
	QMMO39878	4.18	2.21	1.89	1.97	1.07	0.57	20.00	40.00	0.53	2.22	4.000
	QMMO36093	4.02	2.05	1.80	1.72	1.15	0.57	30.00	50.00	0.51	2.23	4.250
	QMMO13073	4.67	2.70	2.46	2.13	1.48	0.57	22.00	37.00	0.58	1.90	5.125
	QMMO85117	3.11	1.80	1.56	1.64	0.74	0.57	16.00	38.00	0.58	2.00	4.250
	AMSC140230	3.85	2.46	1.89	1.97	1.23	0.49	22.00	36.00	0.64	2.04	4.750
	AMSC140230	4.10	2.46	2.05	2.05	1.23	0.57	21.00	37.00	0.60	2.00	4.000
MEAN: <i>Biomphalopa</i> <i>recava</i>	7 adult specimens	3.89	2.21	1.87	1.85	1.09	0.55	22.43	40.29	0.57	2.09	4.375
<i>Amfractaropa</i> <i>bretti</i>	QMMO11716	3.52	1.80	1.07	1.15	1.23	0.49	44.00	121.00	0.51	3.31	4.125
	QMMO11716	2.87	1.48	0.57	1.39	1.15	0.49	37.00	111.00	0.51	5.00	4.000
	QMMO59545	3.28	1.72	1.07	1.48	1.15	0.49	39.00	105.00	0.53	3.08	4.125
	QMMO11716	2.95	1.39	0.98	1.15	1.07	0.49	43.00	100.00	0.47	3.00	3.375
	AMSC140230	3.03	1.64	0.82	1.23	0.90	0.49	41.00	83.00	0.54	3.70	4.000
MEAN: <i>Amfractaropa</i> <i>bretti</i>	5 adult specimens	3.13	1.61	0.90	1.28	1.10	0.49	40.80	104.00	0.51	3.62	3.93

Range extension and genetic structure of the narrowly-restricted slider skink, *Lerista rochfordensis* Amey and Couper, 2009 (Reptilia: Scincidae)

Amey, A.P.¹

Worthington Wilmer, J.¹

Blomberg, S.P.²

Couper, P.J.¹

1. Corresponding authors email: andrew.amey@qm.qld.gov.au Queensland Museum, PO Box 3300, South Brisbane Qld 4101; 2. School of Biological Sciences, University of Queensland, St. Lucia, Qld. 4072.

Citation: Amey, A.P., Worthington Wilmer, J., Blomberg, S.P. & Couper, P.J. 2018. Range extension and genetic structure of the narrowly-restricted slider skink, *Lerista rochfordensis* Amey and Couper, 2009 (Reptilia: Scincidae). *Memoirs of the Queensland Museum – Nature* 61: 29–41 Brisbane. ISSN 2204-1478 (Online), ISSN 0079-8835 (Print). Accepted on: 9 October 2017. Published online: 17 May 2018

<https://doi.org/10.17082/j.2204-1478.61.2018.2017-09>

LSID urn:lsid:zoobank.org:pub:E2DAA7F9-7A42-4CA7-B2E9-9D0F66AD9C0F

ABSTRACT

Recent field surveys have collected more information on the poorly known species, *Lerista rochfordensis*. Previously known only from one dry rainforest patch of around 2000 hectares in northern Queensland, the species was discovered in a neighbouring patch, 8 km distant, itself about 1600 hectares in extent. The two populations are separated by cleared grazing land and the Kirk River, an ephemeral tributary of the Burdekin River. Statistically significant but comparatively small genetic and morphological divergence was observed between the two populations, suggesting they should still be considered conspecific under the Evolutionary Species Concept but are undergoing allopatric speciation. □ *Lerista rochfordensis*, slider skink, Queensland.

The genus *Lerista* Bell, 1833 is an endemic Australian monophyletic group of spheno-morphine skinks showing varying degrees of adaptation to the subsoil environment. Limb reduction is a prominent feature of their evolution, having occurred independently at least ten times within the lineage (Skinner *et al.* 2008). The genus appears to have undergone an ‘explosive radiation’ into newly-developed arid environments within the last 13 million years (Kendrick 1988; Skinner *et al.* 2008) and is the second-most speciose reptile genus in Australia with 96 recognised species, exceeded only by another skink genus, *Ctenotus* Storr, 1964 (Cogger 2014).

Lerista rochfordensis was described in 2009 from specimens collected in a dry rainforest

patch, Rochford Scrub, in northern Queensland (Amey & Couper 2009). It was diagnosed from all other species of *Lerista* by ‘forelimb absent with no groove or other indication, hindlimb 5–8% SVL with a single clawed digit, and five supraciliaries’. The describers considered it to qualify as Vulnerable under the Australian Environment Protection and Biodiversity Conservation Act 1999 (Australian Government 1999) under criteria D2: ‘Populations with a very restricted area of occupancy (typically less than 20 km²) or number of locations (typically 5 or fewer) such that it is prone to the effects of human activities or stochastic events within a very short time period in an uncertain future, and is thus capable of becoming endangered or extinct in a very short time period.’ The collection information available at the time indicated that

TABLE 1. Morphological measurements used and their definitions.

1. Snout-vent length (mm).	21. No. paravertebrals.
2. Head length (tip of snout to posterior margin of parietals, mm).	22. No. supraoculars contacting frontal.
3. Head width (widest point, mm).	23. No. enlarged nuchals.
4. Rostral scale length (anteriormost point to tip of projection between nasal scales, mm).	24. No. supraciliaries.
5. Nasal scale length (anterior to posterior margins, mm).	25. 1st supraciliary contacts 2nd loreal.
6. Length of contact between nasal scales (mm).	26. 1st supraciliary contacts presubocular.
7. Naris width (mm).	27. 1st supraciliary contacts frontal.
8. Internarial distance (distance between the two nostrils, mm).	28. No. preoculars.
9. Eye-naris distance (anterior margin of eye to posterior margin of naris, mm).	29. No. presuboculars.
10. Rostral-frontal distance (posterior median projection of rostral to anterior margin of frontal, mm).	30. No. palpebrals.
11. Supraocular width (mm).	31. No. postoculars.
12. Eye width (mm).	32. 1st temporal contacts postocular.
13. Supralabial-ear (distance from posterior edge of last supralabial to anterior margin of ear, mm).	33. 1st temporal contacts parietal.
14. Eye-ear (distance from posterior margin of eye to anterior margin of ear, mm).	34. 1st temporal contacts 2nd temporal.
15. Paravertebral scale width (mm).	35. No. scales between last supralabial and ear.
16. 2nd paravertebral scale width (mm).	36. No. scales between last infralabial and ear.
17. Mid-ventral scale width (mm).	37. No. infralabials.
18. Width at midbody (mm).	38. No. infralabials contacting postmental.
19. Hind limb length (mm).	39. Hind limb length (no. body scales).
20. No. midbody scale rows.	40. No. lamellae under toe.
	41. No. toe supradigitals.

it occurred at two localities, Rochford Scrub and Boori Station, separated by about 20 km. However, further research has shown this to be incorrect; the Boori Station locality is in fact less than 2 km from the other records and still within the Rochford Scrub. The corrected locality gives a known area of occupancy of less than half a square kilometre and, if all of Rochford Scrub is suitable habitat, a possible occupancy area of only about 20 km². Rochford Scrub, the only known locality for this species, is not protected except by the efforts of the current lease-holders who graze cattle on the encompassing property. The species thus

seems to be very vulnerable to disturbances such as fire, over-grazing and mining.

Surveys of remnant vegetation of Queensland have enabled the mapping of dry rainforests (otherwise known as vine thickets, see Kahn & Lawrie 1987) in northern Queensland (Queensland Department of Science Information Technology and Innovation 2013). These maps show another, similarly-sized patch of dry rainforest, the Barrabas Scrub, in close proximity to Rochford Scrub (Fig. 1). This patch had not been previously surveyed for reptiles. Since dry rainforest appears to be a key habitat for *Lerista* in northern

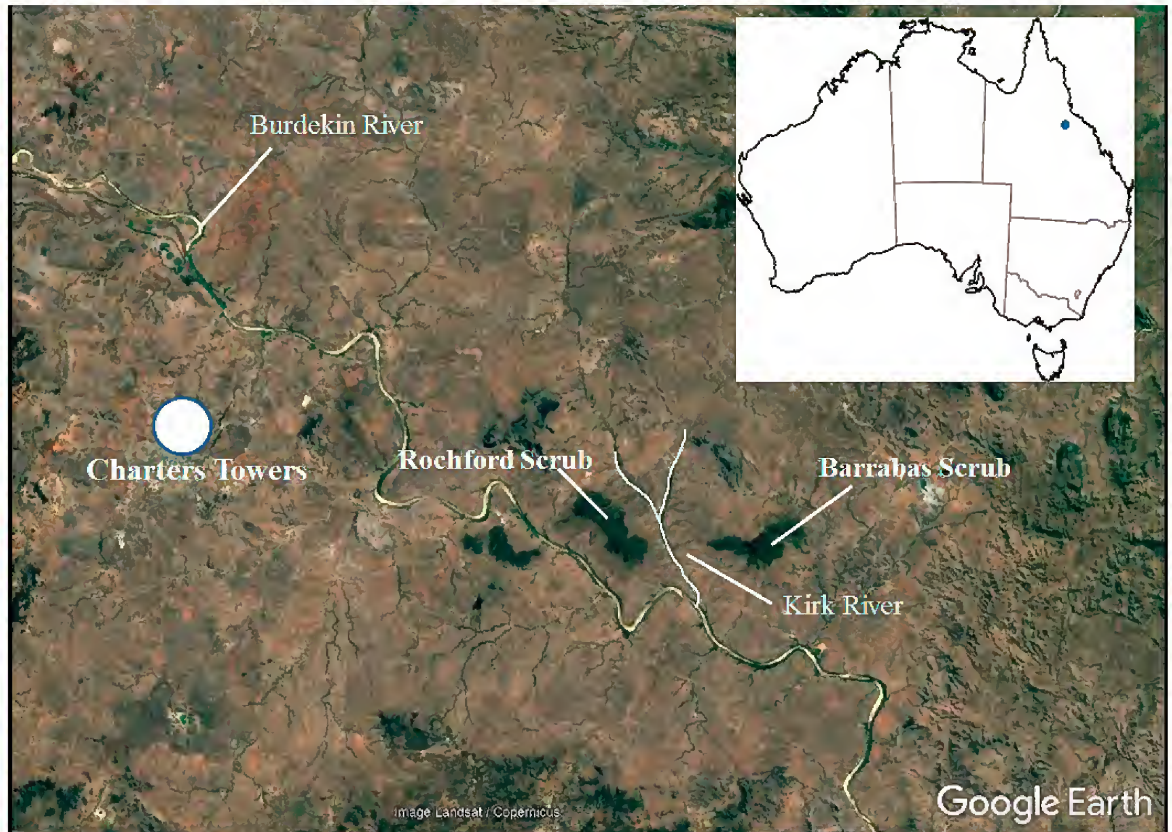


FIG. 1. Map showing Rochford and Barrabas Scrubs, separated by the Kirk River, collection localities for *Lerista rochfordensis*.

Queensland (Amey 2012; Amey & Couper 2009), we targeted this site to discover whether it harboured *Lerista*, and what relationship this population might have to that in Rochford Scrub. The Rochford Scrub population was revisited to obtain genetic samples which had not been previously collected. As *Lerista* were found in Barrabas Scrub, this allowed us to compare the two populations both genetically and morphologically to assess whether they are best thought of as distinct taxa or as conspecific.

METHODS

Survey. Rochford and Barrabas Scrubs were investigated a few days apart in September, 2014. Both have been mapped as consisting of Regional Ecosystem 11.5.15, defined as 'Semi-evergreen vine thicket on remnant Tertiary

surfaces' (Sattler & Williams 1999). Some parts of Rochford Scrub also have a small proportion (30%) of *Acacia* and *Eucalyptus* woodlands (R.E. 11.7.2 and 9.7.2), which are not present at Barrabas. Rochford is approximately 20 km² in extent, Barrabas 23 km². They are approximately 5 km apart and separated by the Kirk River, an ephemeral tributary of the Burdekin River. Both occur on pastoral leases. All specimens were collected by hand, commonly in friable soil under logs. Five specimens were vouchered from Rochford Scrub and eight from Barrabas. All specimens were lodged at the Queensland Museum.

We tested whether the two populations should be considered as distinct taxa or conspecific under the Evolutionary Species Concept of Simpson (1961) using morphology and genetics.

Morphology. Measurements of preserved voucher material were made as per the methods outlined in Couper *et al.* (2016). Variables used are given in Table 1. Scale definitions follows Lillywhite (2008). Specimens examined are listed in Appendix 1.

Statistical Analysis of Morphological Data.

In order to test for morphological differences between the two study populations, we took two approaches. A common approach to classification is to use supervised learning (*sensu* Mohri *et al.* 2012), which aims to find the best way to classify organisms into pre-defined groups, on the basis of several morphological characters. In taxonomy, the most commonly used supervised learning technique is Discriminant Function Analysis (DFA), developed by Fisher (1936), but applied widely since then (see for a review in the context of morphometrics Breitman *et al.* 2013; and Crochet *et al.* 2003 for examples of DFA in lizard taxonomy). A serious problem for DFA is that there are often many more variables than cases (i.e., small N , large p), which makes the application of traditional DFA methods impossible, as these approaches require the inversion of covariance matrices which are then not of full rank (Mitteroecker & Bookstein 2011). Many methods have been proposed to overcome this issue (Sharma & Paliwal 2015). We used a commonly used approach, regularisation, in order to address this small sample size problem. Regularisation methods impose extra constraints on the solution to optimisation problems that can result in shrinkage of parameter estimates (which minimises overfitting) and can allow the construction of sparse solutions such that some parameter estimates may be set to zero, effectively allowing a form of automatic variable selection (Tibishirani 1996). We analysed the forty-one morphological characters using regularised discriminant function analysis (RDA; Friedman 1989). RDA accounts for multicollinearity among variables, and is especially useful in cases where there are more variables than observations, as in our data set. RDA uses a two-parameter regularisation function in order to restrict the outcomes of the analysis to more plausible values. In effect, this regularisation causes the class covariance

matrices to be 'shrunk' towards a multiple of the identity matrix, with the multiplier being the mean of the eigenvalues of the class covariance matrix (see Friedman 1989 for details). RDA was conducted using the *klaR* package for R (R Core Team 2017; Weihs *et al.* 2005). We excluded two specimens due to missing data, resulting in a classification rule based on eight specimens from each locality (Barrabas, Rochford). We first performed a grid search to find the values of the two parameters (λ and γ) that minimised the classification error rate. We then fitted the RDA model to the data using the obtained values for these two parameters, with equal probability priors for the two classes. We calculated posterior probabilities of membership for the two localities and we applied a classification rule that assigned class membership if the probability of membership was greater than 0.5. We computed the Correctness, Accuracy, Ability to Separate and Confidence of the classification, according to the methods of Garczarek (2002) using R package *klaR*.

Our first approach using DFA seeks to achieve maximum separation of classes based on all variables. Our second approach was to try to reduce the number of variables necessary to provide a more parsimonious classification rule. To do this, we used regularised logistic regression. We used L_1 norm regularisation (i.e., the Lasso, Tibishirani 1996) which allows for simultaneous shrinkage and variable selection, as coefficients for uninformative variables are set to zero. We estimated the regularisation parameter (λ , different from the RDA λ , above) using leave-one-out cross validation, with our optimality criterion being the minimisation of the misclassification error (or equivalently, to maximise Correctness). We performed logistic regression using locality as the response variable (Barrabas = 0, Rochford = 1), with the logit link function. Analysis was performed using the *glmnet* package for R (Friedman *et al.* 2010). We calculated probabilities of class membership and assigned specimens to their most likely locality, as above. In addition, we predicted the locality for the two Rochford specimens that were deleted from the RDA

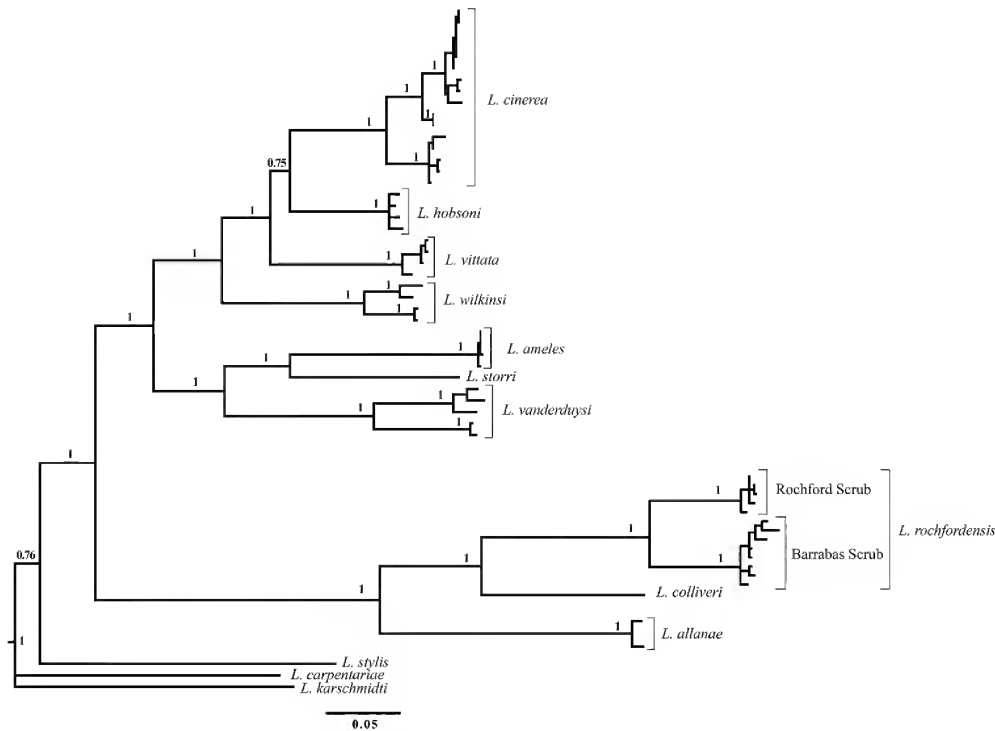


FIG. 2. Majority rule consensus tree of Queensland *Lerista* species and outgroup taxa based on four independent runs of the concatenated data set combining multiple loci (12S, 16S, ND4, flanking tRNAs and nuclear ATPs β). Branches with < 60% support were collapsed and posterior probabilities are indicated above the branches. Scale bar represents 5% of uncorrected sequence divergence.

analysis due to missing data. We also computed Garczarek's (2002) performance measures for the logistic regression classifier using R package klaR.

GENETICS

DNA extraction and sequencing. Tissues from the *Lerista* specimens collected at Rochford (n = 5) and Barrabas (n = 8) Scrubs were sequenced for the same 4 gene regions as used in the Skinner (2007, 2010), Skinner *et al.* (2008), Amey and Worthington Wilmer (2014) and Couper *et al.* (2016) studies of *Lerista* and other *Sphenomorphus*-group scincid lizards. These were mitochondrial DNA (mtDNA) loci 12S and 16S ribosomal rRNA (12S, 16S) and NADH dehydrogenase subunit 4 (ND4) including adjacent transfer tRNA fragments tRNA-His, tRNA-Ser and tRNA-Leu (tRNAs) and

the nuclear ATP synthetase- β subunit intron (nucATP). The sequences were then slotted into the existing alignment and phylogeny generated for Couper *et al.* (2016), which showed that the *L. allanae* group (*L. allanae* (Longman, 1937), *L. colliveri* Couper and Ingram, 1992 and *L. rochfordensis*) as a distinct sister group to the *L. wilkinsi* group taxa.

Total genomic DNA was extracted from all tissues using NucleoSpin Tissue Kits (Macherey-Nagel). The loci 12S, 16S and nucATP were successfully amplified using the primers and annealing conditions as detailed in Skinner (2007; 2010, see Table 1 in either paper). Amplification of the mtDNA ND4 region was obtained using the Arevalo *et al.* (1994) ND4 primers 'ND4' (also in Table 1 of Skinner 2007; Skinner 2010) and 't-Leu' at a 52° C annealing temperature. PCR products were either sequenced directly or gel purified (Macherey-Nagel Gel and PCR

purification kit) and sequencing reactions were carried out according to standard ABI PRISM dye labeled dideoxy terminator sequencing protocols using BigDye Terminator version 3.1. Sequences from the new specimens have been deposited in GenBank nucleotide sequence database and are detailed for each specimen examined in Appendix 2.

Phylogenetic analyses. Chromatographs were checked and all sequences were aligned for each locus using Geneious v 7.1.9 (Kearse *et al.* 2012). Initial alignment of sequences from within a sampling locality was performed using the default settings for the Geneious alignment function (Global Alignment, 93% similarity cost matrix, the highest setting). A consensus alignment of all pre-aligned groups of sequences for each locus was then performed, again implementing the default Geneious multiple alignment function (Kearse *et al.* 2012). All alignments were checked by eye and manual adjustments were made as necessary. Translation of the ND4 region was done to check the appropriate reading frame for codon positions and to identify where the protein coding region ended and the flanking three tRNAs began. The tRNAs were combined into a single dataset due to their short length and functional similarity (Skinner 2007; Skinner *et al.* 2008). The total combined dataset (12S, 16S, ND4, tRNAs and nucATP) for all individuals was manually constructed in Se-Al v 2.0a10 (Rambaut 1996). Prior to phylogenetic analyses, models of sequence evolution/substitution patterns for each of the loci including ND4 first, second and third codon positions were calculated independently and determined by the Akaike information criterion (AIC) in jModeltest v 2.1.3 (Guindon & Gascuel 2003; Posada 2008). Skinner (2010) tested eight different data partitioning strategies and found that a combination of seven partitions (12S, 16S, ND4 first, second and third codon positions, flanking tRNAs and nucATP) provided the best fit to the data. We therefore chose this partitioning strategy for our analyses.

Bayesian phylogenetic analyses were carried out in MrBayes v 3.2.1 (Ronquist *et al.* 2012) and posterior probabilities were calculated using a Markov chain, Monte Carlo (MCMC)

sampling approach. Likelihood (lset) and prior (prset) parameters were then set for each of the 7 data partitions within the total concatenated data set (2833 bp). By default MrBayes v 3.2.1 performs two independent runs. We ran the analysis twice so that four independent runs were performed. For each run, starting trees were random and 4 simultaneous Markov chains were run for 5000000 generations with trees sampled every 1000 generations resulting in a total of 20000 saved trees over the four runs. Burn-in values for each run were set at 1000000 generations (1000 trees) after empirical values of stabilizing likelihoods and the average standard deviation of the split frequencies reached less than 0.01 indicated that convergence of the MCMC chains had been reached. The production of identical consensus trees and their posterior probabilities from each of the MrBayes runs (viewed in FigTree v1.4.2, <http://tree.bio.ed.ac.uk/software/figtree/>) was taken as evidence that the chains had been run for a sufficient number of generations. A final combined majority rule consensus tree from the four independent runs, was generated in PAUP* v 4.b.10 (Swofford 2002) by sequentially importing the four MrBayes tree files (.t files); excluding the first 1000 trees of each tree file and retaining the previous 4001 trees in memory (MrBayes starts its first topology at time zero, resulting in 5001 trees sampled over 5 million generations). The resulting consensus tree was therefore constructed from 16004 trees. The posterior probabilities on the consensus tree are indicated only where branch support is greater than 0.5 (Posada & Crandall 1998). Inferred relationships were considered strongly supported where indicated by Bayesian posterior probabilities (BPP) of ≥ 0.95 (Huelsenbeck *et al.* 2001).

RESULTS

Specimens of *Lerista* were obtained at both Rochford and Barrabas Scrubs. Although no rigorous method of estimating population size was applied, the short collecting time (half a day at each site) and small area surveyed suggests good populations are present at both localities. The Barrabas Scrub population

TABLE 2. Parameters and estimates for the Lasso Logistic Regression analysis, forming the classification rule.

Parameter	Estimate
Intercept	16.0514
No. preocular scales	0.0247
No. presubocular scales	-0.4738
No. scales between last supralabial and ear	-1.2416
Hind limb length (no. body scales)	-0.2530
No. lamellae under the toe	-1.1181
No. toe supradigitals	-0.1714

conformed with the diagnosis of *L. rochfordensis* given in its description (Amey & Couper 2009, and see above).

Morphology. Regularised Discriminant Analysis. The grid search for the optimal values of the regularisation parameters that minimise the misclassification error were covariance shrinkage: $\gamma = 0.053$ and regularisation parameter $\lambda = 1$. Note that when $\lambda = 1$, RDA reduces to LDA. The Correctness index was equal to 1; all specimens were classified to their correct locality. The Accuracy and Ability to Separate were both 0.79, indicating that the two classes were well separated by the classification rule. The Confidence in the classification was 0.89, indicating high confidence. Classwise Confidence was 0.87 for Barrabas and 0.91 for Rochford.

Lasso Logistic Regression. The regularisation parameter (λ) that minimised the classification error rate was equal to 0.101. We used this value to fit the Lasso logistic regression model. This resulted in the retention of 6 explanatory

variables, with 42.54% of the deviance explained by the model (Table 2). Predicted class membership for all specimens was perfect, i.e., Correctness = 1. Accuracy was 0.191 and Ability to Separate was 0.394, considerably lower than for the RDA analysis. The Confidence index was 0.697. Classwise confidence was 0.682 for Barrabas and 0.710 for Rochford. Confidence was again lower than for the RDA analysis. In addition, the two specimens that were not used to build the logistic regression were assigned to their correct locality. Both were assigned to Rochford, with probabilities 0.829 and 0.808.

Molecular data. The phylogenetic analysis clearly supports *L. rochfordensis* as a monophyletic species (BPP = 1.0), which is split into two strongly supported populations relating to Rochford and Barrabas Scrubs (BPP = 1.0) (Fig. 2). Estimates of uncorrected sequence divergence also support conspecific classification with all levels of sequence divergence among the two populations being well below the average divergence across all loci among all currently sequenced *Lerista* species (Table 3).

DISCUSSION

Analysis of the morphological dataset, showing phenetic similarity, combined with the genetic, suggests that the two populations are distinct but very closely related. With no single character distinguishing them and low sequence divergence, they are best thought of as conspecific populations.

Our morphological analyses suggest that the two populations can be separated using the characters we measured, but with a minimum

TABLE 3. Average sequence divergence for *L. rochfordensis*.

Locus	Within Rochford Scrub	Within Barrabas Scrub	Between Rochford and Barrabas Scrubs	Ave. among all <i>Lerista</i> species
12S	0.00%	0.12%	2.46%	8.61%
16S	0.06%	0.05%	1.06%	6.52%
ND4	0.26%	0.43%	3.62%	13.45%
tRNAs	0.21%	0.00%	3.61%	12.37%
nucATP	0.00%	0.08%	0.00%	3.82%

of 6 characters required to correctly distinguish the populations via Lasso logistic regression, although with considerably less confidence than when using the entire morphological data set of 42 characters using RDA. However, there are some caveats. Firstly, our models were trained on the full data set of 8 specimens from each population. It is therefore unsurprising that the models were able to correctly predict class membership of the training data set. The ability to predict population membership for new, out of sample specimens is likely to be lower, although the two specimens that were used for out of sample prediction were assigned correctly with high probability. Nevertheless, our analyses are based on only 18 specimens in total, and our results must be interpreted cautiously. Secondly, our classification rules apply only to the two populations (Barrabas and Rochford) that were available. An analysis of more populations might lead to different classification rules. Also, our classification rules apply to the 41 morphological characters in our data set. There may be other characters that we did not measure that may provide higher confidence in the classification, or better accuracy or ability to separate. This may apply to new single characters or different combinations of multiple characters. Overall, it appears that the two populations have evolved morphological differences which can delimit the two populations, but only with some effort. There is currently no single character that can be used to differentiate the populations.

The biogeographical history of *L. rochfordensis* is as yet unclear. Pre-clearing maps show that Rochford and Barrabas Scrubs were isolated from each other by low open Eucalypt woodland prior to European modification of the landscape (Regional Ecosystem 9.12.1a, Queensland Department of Science Information Technology and Innovation 2018). Our surveys show that the northern Queensland *Lerista* assemblage appears to be dependent on loose, friable soil that they can 'swim' through. In northern Queensland at least, this habitat can be extremely patchy. This may explain the link between some species of *Lerista* and dry rainforest, which is also often correlated with

deep, coarse sands (Kahn & Lawrie 1987). The factors underlying the formation and retention of the dry rainforest scrubs in this part of Queensland are poorly understood but likely to be stochastic and idiosyncratic for each scrub (Kahn & Lawrie 1987). Overall, however, evidence indicates that they appeared in north Queensland during relatively recent Holocene time-frames (Fensham 1995). The populations of *Lerista* within Rochford and Barrabas are distinct from each other but the low level of distinctiveness suggests they have only recently diverged. This appears to be an example of the early stages of allopatric speciation in response to vicariance.

When present, *Lerista* can be common but their ability to migrate between patches of suitable habitat is likely to be limited. This can lead to the appearance of healthy populations which are nonetheless naturally fragmented and vulnerable to habitat destruction.

The discovery of a second population of *L. rochfordensis* in another dry rainforest scrub certainly improves the species' prospects of long term survival. Both scrubs, although without legal protection, are managed by sympathetic leaseholders. For example, Barrabas Scrub is fenced to restrict cattle access. The species appears to be quite abundant at both sites, judging by catching effort, although neither has been exhaustively surveyed to determine whether it occurs throughout each scrub. However, there is no cause to regard *L. rochfordensis* as secure and an objective analysis retains its status as Vulnerable, if not a higher category. It is only known from two locations of around 20 km² in extent each, which renders it "prone to the effects of human activities or stochastic events within a very short time period in an uncertain future, and is thus capable of becoming endangered or extinct in a very short time period." (Australian Government 1999). The scrubs remain unprotected and reliant on the goodwill of the leaseholders, which they currently enjoy. However, some events are largely beyond leaseholder control, such as fire and, in particular, mining activity. The area has a long history of gold mining and mining has occurred very close to both scrubs. Furthermore, there is significant

divergence between the two populations. A loss of one population, while not signifying extinction of a species, is still a significant loss of biodiversity.

ACKNOWLEDGEMENTS

This research was funded by a Research Grant (214-24) from the Australian Biological Resources Study (Australian Government) and further supported by the Queensland Museum. We gratefully acknowledge the courtesy and hospitality of the following who generously allowed access to the collecting sites; Vince Cerqui (Amity Station) and David Hood (Kirkton Station). Collections were made under the Queensland Government Museum License WIMU09571411 and procedures were in accordance with the Queensland Museum Animal Ethics Committee Permit 12-01.

LITERATURE CITED

- Amey, A. 2012. Mount Cooper Striped Skink, *Lerista vittata* Greer, McDonald & Lawrie, 1983. Pp. 232–233. In, Curtis, L.K., Dennis, A.J., McDonald, K.R., Kyne, P.M. & Debus, S.J.S. (eds), *Queensland's Threatened Animals* (CSIRO: Collingwood).
- Amey, A.P. & Couper, P.J. 2009. A new limb-reduced skink (Scincidae: *Lerista*) from the dry rainforest of north Queensland, Australia. *Zootaxa*, **2173**: 19–30.
- Amey, A.P. & Worthington Wilmer, J. 2014. Morphological diversity and genetic structure within *Lerista kalumburu* Storr, 1976 (Squamata: Scincomorpha: Sphenomorphidae) – taxonomic implications. *Zootaxa*, **3821**: 239–252. <http://dx.doi.org/10.11646/zootaxa.3821.2.4>
- Arevalo, E., Davis, S.K. & Sites, J.W. 1994. Mitochondrial DNA sequence divergence and phylogenetic relationships among eight chromosome races of the *Sceloporus grammicus* complex (Phrynosomatidae) in central Mexico. *Systematic Biology*, **43**: 387–418. <http://dx.doi.org/10.1093/sysbio/43.3.387>
- Australian Government 1999. Environment Protection and Biodiversity Conservation Act C2016C00667, Canberra, ACT. Available from: <https://www.legislation.gov.au/Details/C2016C00667> (Accessed 28 June, 2016).
- Bell, T. 1833. Characters of two new genera of reptiles. *Proceedings of the Zoological Society of London*, **1**: 98–99. <http://dx.doi.org/10.1111/j.1469-7998.1833.tb06430.x>
- Breitman, M.F., Morando, M. & Avila, L.J. 2013. Past and present taxonomy of the *Liolaemus lineomaculatus* section (Liolaemidae): Is the morphological arrangement hypothesis valid? *Zoological Journal of the Linnean Society*, **168**: 612–668.
- Cogger, H.G. 2014. *Reptiles & Amphibians of Australia* (7th ed.). (CSIRO Publishing: Collingwood).
- Couper, P.J., Amey, A.P. & Worthington Wilmer, J. 2016. Cryptic diversity within the narrowly endemic *Lerista wilkinsi* group of north Queensland – two new species (Reptilia: Scincidae). *Zootaxa*, **4162**: 61–91. <http://doi.org/10.11646/zootaxa.4162.1.3>
- Couper, P.J. & Ingram, G.J. 1992. A new species of skink of *Lerista* from Queensland and a re-appraisal of *L. allanae* (Longman). *Memoirs of the Queensland Museum*, **32**: 55–59.
- Crochet, P.A., Geneiz, P. & Ieich, I. 2003. A multivariate analysis of the fringe-toed lizards of the *Acanthodactylus scutellatus* group (Squamata: Lacertidae): Systematic and biogeographical implications. *Zoological Journal of the Linnean Society*, **137**: 117–155.
- Fensham, R. 1995. Floristics and environmental relations of inland dry rainforest in north Queensland, Australia. *Journal of Biogeography*, **22**: 1047–1053.
- Fisher, R.A. 1936. The use of multiple measurements in taxonomic problems. *Annals of Eugenics*, **7**: 179–188. <http://dx.doi.org/10.1111/j.1469-1809.1936.tb02137.x>
- Friedman, J., Hastie, T. & Tibishirani, R. 2010. Regularization paths for generalized linear models via coordinate descent. *Journal of Statistical Software*, **33**: 1–22.
- Friedman, J.H. 1989. Regularised discriminant analysis. *Journal of the American Statistical Association*, **84**: 165–175.
- Garczarek, U.M. 2002. Classification Rules in Standardized Partition Spaces. Thesis, University of Dortmund, Dortmund.
- Guindon, S. & Gascuel, O. 2003. A simple, fast and accurate algorithm to estimate large phylogenies by maximum likelihood. *Systematic Biology*, **52**: 696–704. <http://dx.doi.org/10.1080/10635150390235520>
- Huelsenbeck, J.P., Ronquist, F., Nielsen, R. & Bollback, J.P. 2001. Bayesian inference of phylogeny and its impact on evolutionary biology. *Science*, **294**: 2310–2314. <http://dx.doi.org/10.1126/science.1065889>
- Kahn, T.P. & Lawrie, B.C. 1987. Vine thickets of the inland Townsville region. Pp. 159–199. In, *The Rainforest Legacy. Australian National Rainforests*

- Study* (Australian Government Publishing Service: Canberra).
- Kearse, M., Moir, R., Wilson, A., Stones-Havas, S., Cheung, M.S., S., Buxton, S., et al. 2012. Geneious Basic: an integrated and extendable desktop software platform for the organization and analysis of sequence data. *Bioinformatics*, **28**: 1647–1649. <http://dx.doi.org/10.1093/bioinformatics/bts199>
- Kendrick, P.G. 1988. Evolution in *Lerista*: Electrophoretic evidence for an explosion. In: *Australian Bicentennial Herpetological Conference*. Australian Society of Herpetologists, Queensland Museum, Brisbane.
- Lillywhite, H.B. 2008. *Dictionary of Herpetology*. (Krieger Publishing Co: Malabar, Florida).
- Longman, H.A. 1937. Herpetological notes. *Memoirs of the Queensland Museum*, **11**: 165–168.
- Mitteroecker, P. & Bookstein, F. 2011. Linear discrimination, ordination, and the visualization of selection gradients in modern morphometrics. *Evolutionary Biology*, **38**: 100–114.
- Mohri, M., Rostamizadeh, A. & Talwalkar, A. 2012. *Foundations of Machine Learning*. (The MIT Press).
- Posada, D. 2008. jModelTest: Phylogenetic model averaging. *Molecular Biology and Evolution*, **25**: 1253–1256. <http://dx.doi.org/10.1093/molbev/msn083>
- Posada, D. & Crandall, K.A. 1998. Modeltest: Testing the model of DNA substitution. *Bioinformatics*, **14**: 817–818. <http://dx.doi.org/10.1093/bioinformatics/14.9.817>
- Queensland Department of Science Information Technology and Innovation 2013. *Copy of the Vegetation Management Act Regional Ecosystem and Remnant Map - Version 6.1. Online RE Map*. Queensland Department of Science Information Technology and Innovation, Brisbane. Accessed on 10 Oct, 2013.
2018. *Copy of the Pre-clearing Regional Ecosystem Map - Version 10.0. Online RE Map*. Queensland Department of Science Information Technology and Innovation, Brisbane. URL: <https://environment.ehp.qld.gov.au/map-request/re-broad-veg-group/> Accessed on 6 Feb, 2018.
- R Core Team 2017. *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing. Available from: <https://www.R-project.org/>.
- Rambaut, A. 1996. *Se-A: Sequence Alignment Editor v2.0a10*. Available from: <http://evolve.zoo.ox.ac.uk>.
- Ronquist, F., Teslenko, M., Van Der Mark, P., Ayres, D.L., Darling, A., Höhna, S., et al. 2012. MRBAYES 3.2: Efficient Bayesian phylogenetic inference and model selection across a large model space. *Systematic Biology*, **61**: 539–542. <http://dx.doi.org/10.1093/sysbio/sys029>
- Sattler, P. & Williams, R. 1999. The Conservation of Queensland's Regional Ecosystems. Environmental Protection Agency, Brisbane.
- Sharma, A. & Paliwal, K.K. 2015. Linear discriminant analysis for the small sample size problem: an overview. *International Journal of Machine Learning and Cybernetics*, **6**: 443–454.
- Simpson, G.G. 1961. *The Principles of Animal Taxonomy*. (Columbia University Press: New York).
- Skinner, A. 2007. Phylogenetic relationships and rate of early diversification of Australian *Sphenomorphus* group scincids (Scincoidea, Squamata). *Biological Journal of the Linnean Society*, **92**: 347–366. <http://dx.doi.org/10.1111/j.1095-8312.2007.00843.x>
2010. Rate heterogeneity, ancestral character state reconstruction and the evolution of limb morphology in *Lerista* (Scincidae, Squamata). *Systematic Biology*, **59**: 723–740. <http://dx.doi.org/10.1093/sysbio/syq055>
- Skinner, A., Lee, M.S.Y. & Hutchinson, M.N. 2008. Rapid and repeated limb loss in a clade of scincid lizards. *BMC Evolutionary Biology*, **8**: 310. <http://dx.doi.org/10.1186/1471-2148-8-310>
- Storr, G.M. 1964. *Ctenotus*, a new generic name for a group of Australian skinks. *Journal of the Royal Society of Western Australia*, **52**: 97–108.
- Swofford, D.L. 2002. *PAUP* Phylogenetic Analysis Using Parsimony (*and other methods) v4*. Sinauer Associates.
- Tibishirani, R. 1996. Regression shrinkage and selection via the lasso. *Journal of the Royal Statistical Society, Series B (Methodological)*, **58**: 267–288.
- Weih, C., Ligges, U., Luebke, K. & Raabe, N. 2005. klaR analyzing German business cycles. Pp. 335–343. In: Baier, D., Decker, R. & Schmitt-Thieme, L. (eds), *Data Analysis and Decision Support* (Springer-Verlag: Berlin).

APPENDIX 1

Voucher specimens examined. All material is held at the Queensland Museum. All geographic coordinates use the datum GDA94.

Lerista rochfordensis (n = 18). QMJ84790 (Rochford Scrub, CQ 20° 06' 49" S, 146° 37' 03" E, holotype); QMJ44385–44386 (Boori Station, border with Amity, CQ, 20° 07' 24" S, 146° 38' 34" E, paratypes); QMJ85002 (Rochford Scrub, CQ, 20° 07' 01" S, 146° 37' 49" E, paratype); QMJ85007 (Rochford Scrub, CQ,

20° 07' 05" S, 146° 37' 43" E, paratype); QMJ93690 (Rochford Scrub, Amity Station, CQ, 20° 06' 44" S, 146° 37' 10" E); QMJ93691–93694 (Rochford Scrub, Amity Station, CQ 20° 06' S, 146° 37' E); QMJ93697 (Barrabas Scrub, Kirkton Station, CQ, 20° 09' 12" S, 146° 42' 57" E); QMJ93698 (Barrabas Scrub, Kirkton Station, CQ, 20° 09' S, 146° 43' E); QMJ93699 (Barrabas Scrub, Kirkton Station, CQ, 20° 09' 10" S, 146° 42' 56" E); QMJ93700–93704 (Barrabas Scrub, Kirkton Station, CQ, 20° 09' S, 146° 43' E).

APPENDIX 2

GenBank sequence numbers for material examined in this study.

Species	12S rRNA	16S rRNA	ND4+tRNAs	ATP
<i>Lerista allanae</i> - Capella 1	KU309145	KU309187	KU309272	KU309229
<i>Lerista allanae</i> - Capella 2	KU309146	KU309188	KU309273	KU309230
<i>Lerista ameles</i> - Mt Surprise 1	KU309147	KU309189	KU309274	KU309231
<i>Lerista ameles</i> - Mt Surprise 2	KU309148	KU309190	KU309275	KU309232
<i>Lerista ameles</i> - Mt Surprise 3	KU309149	KU309191	KU309276	KU309233
<i>Lerista ameles</i> - Mt Surprise 4	KU309150	KU309192	KU309277	KU309234
<i>Lerista cinerea</i> - Warrawee Station 1	KU309151	KU309193	KU309278	KU309235
<i>Lerista cinerea</i> - Warrawee Station 2	KU309152	KU309194	KU309279	KU309236
<i>Lerista cinerea</i> - Warrawee Station 3	KU309153	KU309195	KU309280	KU309237
<i>Lerista cinerea</i> - Warrawee Station 4	KU309154	KU309196	KU309281	KU309238
<i>Lerista cinerea</i> - Warrawee Station 5	KU309155	KU309197	KU309282	KU309239
<i>Lerista cinerea</i> - Warrawee Station 6	KU309156	KU309198	KU309283	KU309240
<i>Lerista cinerea</i> - Bletchington Park	KU309157	KU309199	KU309284	KU309241
<i>Lerista cinerea</i> - Gregory Development Rd	KU309158	KU309200	KU309285	KU309242
<i>Lerista cinerea</i> - Rishton Scrub 1	KU309159	KU309201	KU309286	KU309243
<i>Lerista cinerea</i> - Rishton Scrub 2	KU309160	KU309202	KU309287	KU309244
<i>Lerista cinerea</i> - Rishton Scrub 3	KU309161	KU309203	KU309288	KU309245
<i>Lerista cinerea</i> - Sellheim Scrub 1	KU309162	KU309204	KU309289	KU309246
<i>Lerista cinerea</i> - Sellheim Scrub 2	KU309163	KU309205	KU309290	KU309247
<i>Lerista cinerea</i> - Sellheim Scrub 3	KU309164	KU309206	KU309291	KU309248
<i>Lerista cinerea</i> - Sellheim Scrub 4	KU309165	KU309207	KU309292	KU309249
<i>Lerista cinerea</i> - Sellheim Scrub 5	KU309166	KU309208	KU309293	KU309250

Appendix 2 continued ...

Species	12S rRNA	16S rRNA	ND4+tRNAs	ATP
<i>Lerista colliveri</i>	KU309167	KU309209	KU309294	KU309251
<i>Lerista hobsoni</i> - Lolworth Homestead 1	KU309168	KU309210	N/A	KU309252
<i>Lerista hobsoni</i> - Lolworth Homestead 2	KU309169	KU309211	KU309295	KU309253
<i>Lerista hobsoni</i> - Lolworth Homestead 3	KU309170	KU309212	KU309296	KU309254
<i>Lerista hobsoni</i> - Pentland	KU309171	KU309213	KU309297	KU309255
<i>Lerista rochfordensis</i> - Barrabas Scrub 1	MF589181	MF589191	MF589212	MF589202
<i>Lerista rochfordensis</i> - Barrabas Scrub 2	MF589182	MF589192	MF589213	MF589203
<i>Lerista rochfordensis</i> - Barrabas Scrub 3	MF589183	MF589193	MF589214	MF589204
<i>Lerista rochfordensis</i> - Barrabas Scrub 4	N/A	MF589194	MF589215	MF589205
<i>Lerista rochfordensis</i> - Barrabas Scrub 5	MF589184	MF589195	MF589216	MF589206
<i>Lerista rochfordensis</i> - Barrabas Scrub 6	MF589185	MF589196	MF589217	N/A
<i>Lerista rochfordensis</i> - Barrabas Scrub 7	MF589186	MF589197	MF589218	MF589207
<i>Lerista rochfordensis</i> - Barrabas Scrub 8	MF589187	MF589198	MF589219	MF589208
<i>Lerista rochfordensis</i> - Rochford Scrub 1	KU309172	KU309214	KU309298	KU309256
<i>Lerista rochfordensis</i> - Rochford Scrub 2	KU309173	KU309215	KU309299	KU309257
<i>Lerista rochfordensis</i> - Rochford Scrub 3	MF589188	MF589199	MF589220	MF589209
<i>Lerista rochfordensis</i> - Rochford Scrub 4	MF589189	MF589200	MF589221	MF589210
<i>Lerista rochfordensis</i> - Rochford Scrub 5	MF589190	MF589201	MF589222	MF589211
<i>Lerista storri</i> - Almaden	KU309174	KU309216	KU309300	KU309258
<i>Lerista vanderduysi</i> - Blackbraes 1	KU309175	KU309217	KU309301	KU309259
<i>Lerista vanderduysi</i> - Blackbraes 2	KU309176	KU309218	KU309302	KU309260
<i>Lerista vanderduysi</i> - Blackbraes 3	KU309177	N/A	N/A	KU309261
<i>Lerista vanderduysi</i> - Glibert Station 1	KU309178	KU309219	N/A	KU309262
<i>Lerista vanderduysi</i> - Glibert Station 2	N/A	KU309220	N/A	KU309263
<i>Lerista vittata</i> - Mt Cooper Station 1	KU309179	KU309221	KU309303	KU309264
<i>Lerista vittata</i> - Mt Cooper Station 2	KU309180	KU309222	KU309304	KU309265
<i>Lerista vittata</i> - Mt Cooper Station 3	KU309181	KU309223	KU309305	KU309266
<i>Lerista vittata</i> - Mt Cooper Station 4	KU309182	KU309224	KU309306	KU309267
<i>Lerista wilkinsi</i> - Torrens Creek 1	KU309183	KU309225	KU309307	KU309268
<i>Lerista wilkinsi</i> - Torrens Creek 2	KU309184	KU309226	KU309308	KU309269
<i>Lerista wilkinsi</i> - Torrens Creek 3	KU309185	KU309227	KU309309	KU309270
<i>Lerista wilkinsi</i> - Torrens Creek 4	KU309186	KU309228	KU309310	KU309271

Appendix 2 continued ...

Species	12S rRNA	16S rRNA	ND4+tRNAs	ATP
Outgroups				
<i>Lerista carpentariae</i>	EF672763	EF672834	EF672975	EF672905
<i>Lerista karlschmidtii</i>	EF672787	EF672858	EF672999	EF672929
<i>Lerista stylis</i>	EF672811	EF672882	EF373023	EF672952

Description of a new species of semi-slug, *Fastosarion comerfordae* sp. nov., from Eungella National Park, mid-eastern Queensland (Gastropoda: Eupulmonata: Helicarionidae)

John STANISIC

Honorary Research Fellow, Biodiversity Program, Queensland Museum, PO Box 3300, South Brisbane Qld 4101, Australia. Email: john.stanisic@qm.qld.gov.au

Citation: Stanisic, J. 2018: Description of a new species of semi-slug, *Fastosarion comerfordae* sp. nov., from Eungella National Park, mid-eastern Queensland (Gastropoda: Eupulmonata: Helicarionidae). *Memoirs of the Queensland Museum – Nature* 61: 43–51. Brisbane. ISSN: 2204-1478 (Online), ISSN: 0079-8835. (Print) Accepted: 16 February 2018. Published online: 17 May 2018

<https://doi.org/10.17082/j.2204-1478.61.2018.2018-05>

LSID urn:lsid:zoobank.org:pub:C16619B0-67AA-4680-9D0A-6647D5972AAF

ABSTRACT

A new semi-slug, *Fastosarion comerfordae* sp. nov., is described from the higher elevations of Eungella National Park in mid-eastern Queensland. Historically the species has been considered to be conspecific with *F. superba* (Cox, 1871) from Mt Dryander, mid-eastern Queensland. Differences in external animal features and penial anatomy are shown to separate the new species from *F. superba*. □ *Fastosarion comerfordae* sp. nov., Gastropoda, Eupulmonata, Helicarionidae, new species, Queensland, Australia.

The rainforests between Sarina and Proserpine, mid-eastern Queensland are significant habitats for a large number of land snails many of which are endemic to the region. Among these are a number of semi-slugs (Fam. Helicarionidae) including records of *Fastosarion superba* (Cox, 1871) which is one of Australia's largest semi-slugs. A recent survey exploring the diversity of invertebrates (including land snails) of Eungella National Park (NP) and surrounding areas (Eungella Biodiversity Project) produced a number of semi-slugs from the area's higher elevations (alt. > 800 m) which included specimens of what were historically considered *F. superba*, together with a large brown semi-slug and several other smaller semi-slugs. In order to establish the identity of the large brown specimens, dissections of the genitalia were carried out on several specimens of both the black and brown varieties with unexpected results. The penial chambers of both colour

forms of the large semi-slug displayed an identical pilaster pattern indicating that these were just different colour morphs of the same species. But more significantly, the pilaster patterns of these Eungella specimens were quite different from true *F. superba* from Mt Dryander indicating that the Eungella specimens were not *F. superba* and represented an undescribed species. These findings are shown to differ from the conclusions of Scott (1995).

This study describes the new species of semi-slug from Eungella NP on the basis of external animal features and reproductive anatomy and presents new additional distribution records for the species. Specimens from Mt Macartney also cited by Scott (1995) as belonging to *F. superba* were dissected and shown to have a markedly different pilaster pattern from both the Mt Dryander and Eungella semi-slugs indicating that this is also an undescribed species that most likely does not belong within *Fastosarion*.

MATERIAL AND METHODS

Material used in this study is held in the collections of the Queensland Museum (QMMO). Studies of shell characters were carried out on specimens in the museum's dry collection (RC) and anatomical studies were based on ethanol preserved samples (SC). Age cohorts in individual lots are identified by the abbreviations A (adult) and SA (subadult). Undescribed species mentioned in this study from the collections of the Queensland Museum are denoted by a family descriptor and an alpha-numeric codon e.g. Helicarionid MQ 10. Specimens were studied using a WILD M5 stereo microscope and anatomical photographs were taken with a NIKON 4200 Coolpix camera with microscope attachment. Shell measurements (height, diameter) were made using callipers with a precision of 0.01 mm. Whorl counts were made to the nearest 0.125 whorl. Three individuals were dissected in order to confirm constancy of reproductive structures.

Abbreviations used. MEQ, mid-eastern Queensland; Mt, Mount; NEQ, north-eastern Queensland; NP, national park; NSW, New South Wales; nvf, notophyll vine forest; SEQ, south-eastern Queensland; SF, State Forest.

SYSTEMATICS

Class GASTROPODA

Infraorder EUPULMONATA

Superfamily HELICARIONOIDEA

Family HELICARIONIDAE

Genus *Fastosarion* Iredale, 1933

Fastosarion Iredale, 1933: 37; 1937: 9.

Vercularion Iredale, 1933: 38; 1937: 8; 1941: 6.

Fastosarion Iredale Smith, 1992: 231; Stanisic *et al.*, 2010: 302.

Type species. *Vitrina superba* Cox, 1871- by original designation.

Taxonomic issues. *Fastosarion* was introduced by Iredale (1933) as a monotypic genus for the large MEQ semi-slug from Mt Dryander,

Vitrina superba Cox, 1871. *Vercularion* Iredale, 1933 (type species. *Helicarion bullaceus* Odhner, 1917 = *Helicarion brazieri* Cox, 1873) was also introduced as a monotypic genus for a large semi-slug from the Wet Tropics, NEQ. Iredale (1937, 1941) expanded the latter genus to include a number of other semi-slugs from northern and central NSW and SEQ. Smith (1992) on advice from the late Ron Kershaw synonymised *Vercularion* with *Fastosarion*. Scott (1995) introduced two additional *Fastosarion* species from MEQ and NEQ. Stanisic *et al.* (2010) further expanded *Fastosarion* to include an additional seven newly described semi-slugs from eastern Australia while stating that the genus as defined was most likely polyphyletic. Hyman & Ponder (2010) introduced *Stanisicarion* to accommodate two of the species (*Helixarion freycineti* Férussac, 1921 and *Vitrina virens* Pfeiffer, 1849) previously included in *Fastosarion* on the basis of differences in male genitalia. Hyman *et al.* (2017) relegated *Fastosarion staffordorum* Stanisic, 2010 to the synonymy of *Mysticarion hyalina* (Pfeiffer, 1855). As a result 10 species still remain in the genus.

Diagnosis. Large semi-slugs, shell ear-shaped, glossy with a complete base, protoconch sculpture of fine, very crowded, weakly notched spiral striae or smooth, teleoconch sculpture smooth with short, arcuate growth ridges present at the sutures and ultra-fine spiral lines. Body colour variable, green to orange-brown and black, sometimes with reddish markings. Shell lappets large, not fused, variously sculptured with wart-like pustules or elongate ridgelets; mantle lobes prominent, finely pustulose with large cephalic shield covering most of the neck. Caudal horn small. Slime network prominent. Genitalia with short bursa copulatrix and vagina. Epiphallus with free ascending and descending arms or with two arms fused (*F. papillosa*, *F. pustulosa*), a retractor caecum situated about half way along its length and a long, coiled flagellum at the epiphallus-vas deferens junction; epiphallus entering penis through a simple pore or spade-like verge (*F. griseola*). Penis relatively long with a prominent sheath, internally with a central longitudinal pilaster and background

pattern of chevron-like, diagonal to obliquely oriented lamellae (*F. superba*), slender, elongate filamentous pilasters (*F. brazieri*, *F. paluma*) or diamond-shaped pustules (*F. ameyi*, *F. aquavivae*, *F. helenkingae*, *F. schelli*); otherwise with corrugated longitudinal pilasters and a penial verge (*F. griseola*) or with central longitudinal pilasters and a background of irregular pustules (*F. papillosa*, *F. pustulosa*).

Range. Currently considered to include species from far north-eastern NSW to the Wet Tropics, NEQ.

Remarks. *Fastosarion* Iredale, 1933 is currently under a detailed morphological and molecular review by Isabel Hyman and Frank Köhler (Australian Museum, Sydney) and molecular results to date confirm that the genus as currently defined is polyphyletic. The inconsistent nature of the diagnosis presented above (based on the assemblage of species currently still assigned to the genus) in regard to the genitalia, in particular the penial chamber, would seem to support such a proposal. Other species currently assigned to *Fastosarion* show dramatically different background patterns of elongate filamentous pilasters, diamond shaped pustules, corrugated longitudinal pilasters (with a penial verge) and irregular pustules (Stanisic, unpubl., Hyman, pers. comm.). A final verdict on the generic status of these species is awaiting the outcome of the abovementioned review.

In the interim *Fastosarion comerfordae* sp. nov. is described and assigned to *Fastosarion* based on the close similarity of the male terminal genitalia to that of the genotype.

Fastosarion comerfordae sp. nov.
(Figs 1, 2, 3, 4A-B)

Fastosarion superba Cox, 1871 auct.; Stanisic et al., 2010: (partim).

Fastosarion superba Cox. Hyman & Ponder, 2010: 47.

Etymology. Named for Deidre Comerford, former Mayoress of the Mackay Regional Council for her support of the Eungella Biodiversity Study.

Preferred common name. Eungella Semi-slug.

Material Examined. All MEQ. Holotype. QMMO85406, animal SC/shell RC, Broken River, Granite Belt Track, Eungella NP (20°10'S, 148°30'E), nvf, under log,

17.xi.2016, J. Stanisic, L. Holcroft. Height of shell 14.03 mm, max. diameter 23.79 mm, min. diameter 18.84 mm, h/maximum d ratio 0.59. Whorls 3.375. Length of preserved animal 60 mm.

Paratypes. QMMO20221, 32A SC/2A RC, 0.5km along Diggings Rd, Eungella NP (21°10'S, 148°24'E), 16.vi.1987, J. Stanisic, D. Potter; QMMO36086, 21A SC/3A RC, lower slopes of Mt Dalrymple, Eungella-Mt William Rd, Eungella NP (21°04'S, 148°35'E), nvf, in discarded palm fronds, 16.v.1990, J. Stanisic, D. & N. Potter; QMMO50272, Eungella NP, 4A SC, Eungella NP (20°54'S, 148°36'E), 26.xii.1993, ANZSES; MO76946, 18A SC, Mt William trig station saddle, Eungella NP (21°01'S, 148°36'E), 8.iii.1994, ANZSES; QMMO19792, 50A SC/1A RC, Broken River, Eungella NP (20°10'S, 148°30'E), nvf, 800 m, xi.1976, M. J. Bishop; QMMO59653, 60A/SA SC, Dalrymple Heights, Eungella NP (21°02'S, 148°36'E), nvf, 1000m, xi.1976, M. J. Bishop.

Other material. QMMO16422, 2A,1SA RC, Eungella, near schoolhouse, Eungella NP, 13.ii.1986, R. Raven; QMMO50850, 1A SC/1A RC, Dalrymple Rd, Eungella NP (21°02'S, 148°36'E), rainforest, pitfall trap, 9.xi.1991, P. Lawless, R. Raven; QMMO11751, 6A,4SA SC/3A RC, Diggings Rd, Eungella NP (21°09'S, 148°29'E), nvf, 8.vii.1982, J. Stanisic; QMMO20177, 8A,5SA SC/1A RC, 0.7 km along Crediton Rd from Broken River turnoff, Eungella NP (21°11'S, 148°31'E), 16.vi.1987, J. Stanisic, D. Potter; QMMO11705, 1A,1SA SC/2A RC, Broken River, Eungella NP (20°10'S, 148°30'E), nvf, 5.vii.1982, J. Stanisic; QMMO59696, 3A SC/1A RC, Eungella NP (20°10'S, 148°30'E), nvf, 800 m, 28.i.1975, K. McDonald; QMMO11747, 1A,1SA SC Finch Hatton Gorge, c. 10km W Finch Hatton, Eungella NP (21°04'S, 148°38'E), nvf, 8.vii.1982; QMMO64901, 1A SC, top of Finch Hatton Gorge (21°03'48"S, 148°38'09"E), nvf, under log, 30.x.1998, J. Stanisic; QMMO77419, 1A SC, Eungella, south at Crediton, Eungella NP (20°11'S, 148°33'E), 750 m, 17.xi.1992, QM Party; QMMO13460, 1J RC, Broken R., Eungella NP (20°10'S, 148°30'E), nvf, litter, 5.vii.1982, J. Stanisic; QMMO50278, 3SA RC, Mt William, Eungella NP (21°01'S, 148°36'E), 17.xii.1993, ANZSES; QMMO50277, 1SA RC, Mt William, Eungella NP (21°01'S, 148°36'E), 16.xii.1993, ANZSES; QMMO50257, 1A SC, Eungella NP (20°52'S, 148°37'E), 22.xii.1993, ANZSES; QMMO50263, 2A1SA SC, Frederickson Property, Eungella NP (21°02'11"S, 148°35'06"E), 14.xii.1993, ANZSES; QMMO50431, 1A1SA SC, between Mt Henry and Mt David, Eungella NP (21°02'S, 148°37'E), 14.xii.1993, ANZSES; QMMO50433, 1SA SC, between Mt David and Mt Dalrymple, Eungella NP (21°02'S, 148°39'E), 18.xii.1993, ANZSES.

Eungella Biodiversity Study material. QMMO86551, 3A SC, Eungella NP, Mt Dalrymple track, Site C-1200 m, (21.015°S, 148.608°E), alt. 1144 m, rainforest, on ground under palm fronds, J. Stanisic, 12.xi.2013; QMMO86552, 3A SC, Eungella NP, Quandong Lodge



FIG. 1. *Fastosarion comerfordae* sp. nov., preserved holotype, Broken R., Eungella NP, MEQ, QMMO85406. Dart-like markings on side of foot arrowed. Scale lines in mm.

environs (21°04.474'S, 148°32.190'E), alt. 900 m, rainforest, on ground under palm fronds, J. Stanisic, 13.xi.2013; QMMO86553, 3A, 2SA SC, Eungella NP, Mt Dalrymple track, Site D-1000 m, (21.059°S, 148.582°E), alt. 971 m, rainforest, on ground under palm fronds, J. Stanisic, 13.xi.2013; QMMO86554, 4A SC, Eungella NP, Mt Dalrymple track, Site C-1000 m, (21.051°S, 148.581°E), alt. 1000 m, rainforest, under logs, J. Stanisic, 13.xi.2013; QMMO86555, 1SA SC, Eungella NP, off Diggings Road, Site D-800m (21.145°S, 148.498°E), alt. 816m, rainforest, J. Stanisic, 13.xi.2013; QMMO86556, 1A SC, Eungella NP, off Dalrymple Road, Site C-800 m, (21.143°S, 148.495°E), alt. 808m, rainforest, under logs, J. Stanisic, 13.xi.2013; QMMO86557, 1A SC, Eungella NP, Mt William, Site A-1200 m, (21.026°S, 148.638°E), alt. 1234 m, rainforest, under logs, J. Stanisic, 14.xi.2013; QMMO86558, 6A SC, Eungella NP, Mt Henry, Site B-1200 m, (21.026°S, 148.627°E), alt. 1164, rainforest, under logs, J. Stanisic, 14.xi.2013; QMMO86559, 4A, 2SA SC, Eungella NP, off Dalrymple Road, Site B-1000 m, (21.036°S, 148.597°E), alt. 972 m, rainforest, under logs, J. Stanisic, E. Window, 15.xi.2013; QMMO86560, 2A SC Eungella NP, off Eungella Dam Road, Site B-800 m. (21.122°S, 148.503°E), alt. 755 m, rainforest, under logs, E. Window, 18.xi.2013; QMMO86561, 2A SC, Eungella NP, off Dalrymple Road, Site A-1000 m, (21.035°S, 148.600°E), alt. 1028 m, rainforest, under logs, E. Window, 20.xi.2013; QMMO86562, 1SA SC, Pelion SF, Owens Creek, Site C-600 m, (21.055°S, 148.636°E), alt. 570 m, rainforest, under logs, E. Window, 25.xi.2013.

Taxonomic issues. *Fastosarion superba* (the Type of the genus) was described from Mt Dryander, MEQ but has also been recognised as occurring in the higher reaches of the Clarke

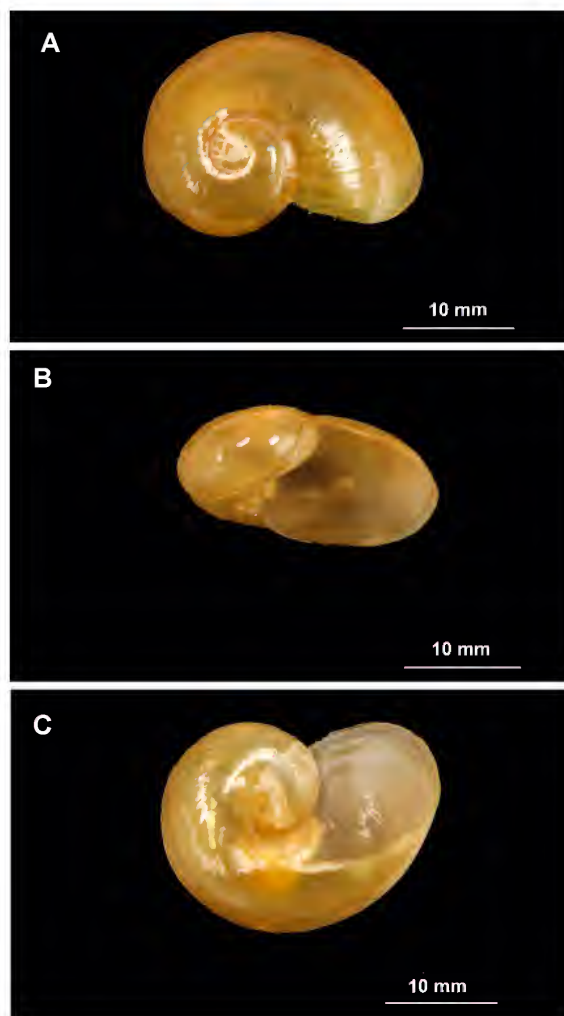


FIG. 2. Shell of *Fastosarion comerfordae* sp. nov., holotype, Broken R., Eungella NP, MEQ, QMMO85406. A, dorsal view; B, apertural view; C, ventral view.

Range in the Eungella NP roughly between Mt Dalrymple and Eungella by various authors (Smith 1992; Scott 1995; Hyman & Ponder 2010; Stanisic *et al.* 2010). Scott (1995) illustrated the terminal genitalia of a Eungella specimen and the penial chamber of one from Mt Dryander assuming that the two were conspecific. Results presented below show that this assumption was incorrect. **Diagnosis.** Large semi-sluggish, shell ear-shaped, glossy with a complete non-membranous base,

protoconch sculpture of fine, very crowded, weakly notched spiral striae, teleoconch sculpture smooth with short, arcuate growth ridges present at the sutures and ultra-fine spiral striae. Body colour variable, orange-brown to black, occasionally black with red markings, and a series of black dart-like lines on the side of the foot below the pedal grooves continuous to the caudal horn. Shell lappets large, not fused, with wart-like pustules. Genitalia with short bursa copulatrix and vagina. Epiphallus entering penis through a simple pore. Penis internally with slender diagonal pilasters arranged in a chevron pattern and a large, central longitudinal pilaster.

Description. *Animal* (Fig. 1. 6A-C). Large semi-slug, body length (in preservative and based on largest specimens from QMMO59653) 52–60 mm (mean 56.56 mm, $n = 16$). Foot long, slender, tripartite, broadly rounded anteriorly, tapered posteriorly; tail long, keeled mid-dorsally with a small caudal horn. Caudal fossa a long vertical slit in tail. Pedal grooves typically aulacopod and united above the tail. Colour (in life) orange-brown to black, occasionally with reddish markings, tripartite foot with outer segments orange to pink and a series of black dart-like lines on the side of the foot below the pedal grooves continuous to the caudal horn. Shell lappets large, right shell lappet subcircular, left shell lappet sickle-shaped, both with wart-like pustules; mantle lobes prominent, finely pustulose with left lobe forming large cephalic shield.

Shell (Figs 2, 3). Shell large, glossy, maximum diameter 19.91–26.15 mm (mean 22.43 mm), minimum diameter 14.66–19.14 mm (mean 16.55 mm), ear-shaped thin and poorly calcified. Whorls 3.125–3.375 (mean 3.250), rapidly expanding. Body whorl expanded, not descending in front, with basal margin complete. Spire and apex flat. Height of shell 12.30–18.95 mm (mean 14.84 mm). Protoconch of 1.5 whorls, sculpture of fine, very crowded, weakly notched spiral striae, teleoconch sculpture with short, arcuate growth ridges present at the sutures and ultra-fine spiral striae. Sutures flat. Whorls rounded above and below the periphery, with internal walls complete. Colour light yellow to golden

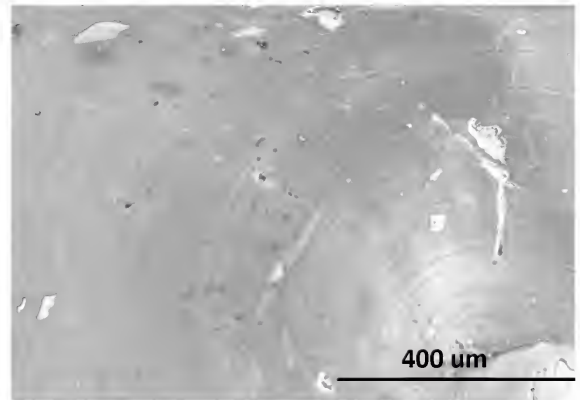


FIG. 3. Microsculpture on protoconch of *Fastosarion comerfordae* sp. nov., Eungella NP, MEQ, QMMO50278.

brown. Based on 10 measured adult shells (QMMO11751, QMMO36086, QMMO20221, QMMO59696, QMMO11705, QMMO19792, QMMO20177).

Genitalia (Fig. 4A, B) Penis long, cylindrical with a thin sheath; internally with relatively coarse, diagonal lamellae arranged in a chevron pattern, and a large, central longitudinal pilaster, pilaster formed by an uplift of the lamellae over a central ridge; verge absent. Epiphallus long, entering penis through a simple pore with equal length ascending and descending arms and a retractor caecum situated halfway along its length, penial retractor muscle inserted on caecum; long, coiled epiphallallic flagellum situated at the epiphallus-vas deferens junction; vas deferens a thin coiled tube. Vagina short, internally with longitudinal thickenings, free oviduct relatively long, bursa copulatrix large with thick stalk, head attached halfway along the prostate-uterus; uterus sacculate with prostate a series of white alveoli appressed to the surface of the uterus for its entire length; hermaphroditic duct convoluted and swollen. Based on five dissected specimens (QMMO19792, QMMO36086, QMMO59696, QMMO86558 [2]).

Radula. (Description based on Hyman & Ponder 2010). Radula with tricuspid central tooth that has a broadly lanceolate mesocone and two small, pointed lateral cusps; lateral teeth strongly bicuspid with large mesocone and endocone reduced to a small point high



FIG. 4. A, terminal genitalia, *Fastosarion comerfordae* sp. nov., Eungella NP, Mt Henry, MEQ, QMMO86558. B-F, penial chambers of various semi-slugs showing main pilaster and pattern of background pilasters. B, *F. comerfordae*, Eungella NP, Mt Henry, MEQ, QMMO86558; C, *F. superba*, Mt Dryander, MEQ, QMMO46334; D, *Helicarionid* MQ10, Mt Macartney, MEQ, QMMO35622; E, *Helicarionid* MQ16, Eungella NP, Quandong Lodge, MEQ, QMMO86552; F, *Eungarion mcdonaldii* Stanisic, 1993, Mt Macartney, MEQ, MO35628; G, *F. brazieri*, Mosman, NEQ, QMMO60553. [BC, bursa copulatrix; DG, prostate; E, epiphallus; EF, epiphallic flagellum; EP, epiphallic pore; ERC, epiphallic retractor caecum; GD, hermaphroditic duct; P, penis; PP, pilasters; PPM, main pilaster; PRM, penial retractor muscle; PS, penial sheath; UV, free oviduct; UT, uterus; V, vagina; VD, vas deferens].

up on the edge of the mesocone, ectocone short; marginal teeth bicuspid with elongate mesocone and short reduced ectocone. Jaw arcuate. Radular formula ~70.21.1.21.70~.

Distribution and habitat. *Fastosarion comerfordae* sp. nov. occurs in the higher elevations (alt. > 800 m) of the Clarke Range in Eungella NP living in moist notophyll vine forest (Fig. 5). The species has also been found along key drainage lines (e.g. Finch Hatton Gorge, Owens Creek) at slightly lower elevations. *F. comerfordae* has been collected on the ground from under forest debris such as discarded palm fronds, logs and rocks. The wide geographic separation of *F. comerfordae* and *F. superba* by the Sarina-Proserpine lowlands is only matched by the diverse nature of their respective habitats. Whereas *F. comerfordae* lives in moist humid notophyll vine forest *F. superba* inhabits drier araucarian vine forest.

Remarks. *Fastosarion comerfordae* sp. nov. can be differentiated from *F. superba* (Cox, 1871) on the basis of both external animal features and penial anatomy. The animal of *F. comerfordae* is brown to black occasionally with red markings and a series of black, dart-like markings on the sides of the foot below the pedal grooves (Fig. 6A–C). In contrast the animal of *F. superba* is greenish-brown and lacks the black, dart-like markings on the sides of the foot. Most adult specimens of *F. comerfordae* range between 50–60 mm while those of *F. superba* range from 60–70 mm. The maximum diameter of *F. comerfordae* shells measured was 26.15 mm compared with the largest *F. superba* shell of 31.66 mm.

The penial chambers of the two species are grossly similar with diagonal lamellae arranged in a chevron pattern and a large, central longitudinal pilaster formed by an uplift of the lamellae over a central ridge. However, in *F. comerfordae* (Fig. 4B) the main pilaster is shorter than *F. superba* and the lamellae are significantly coarser and thicker than the slender and delicate lamellae of *F. superba* (Fig. 4C). No other semi-slug species (Helicarionid MQ 10) with a similar penial chamber pilaster pattern has yet been found elsewhere in mid-eastern Queensland. The penial chamber of specimens from Mt Macartney cited by Scott

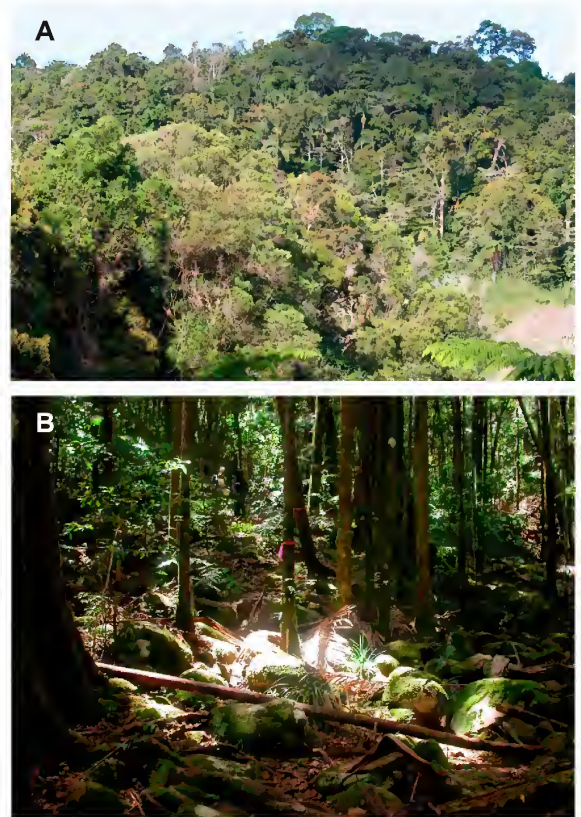


FIG. 5. Habitat of *Fastosarion comerfordae* sp. nov. A, Eungella rainforest (alt. 900 m); B, microhabitat on Mt Dalrymple track (alt. 1000 m).

(1995) as being conspecific with this species features a series of diamond shaped pustules which aggregate apically into a relatively short longitudinal pilaster (Fig. 4D).

An undescribed species (Helicarionid MQ 16) occurs sympatrically with *F. comerfordae* but can be distinguished from the species through its smaller size and beige animal colour (Fig. 5D). Anatomically, the terminal genitalia of Helicarionid MQ 16 are smaller and the penial chamber features a short central pilaster that is bifurcated basally with a background pattern of sub-rectangular to polygon-shaped pustules (Fig. 4E).

Stanisic (1993) described *Eungarion mcdonaldii* from the upper elevations of the Clarke Range, MEQ. This species is markedly smaller (mean

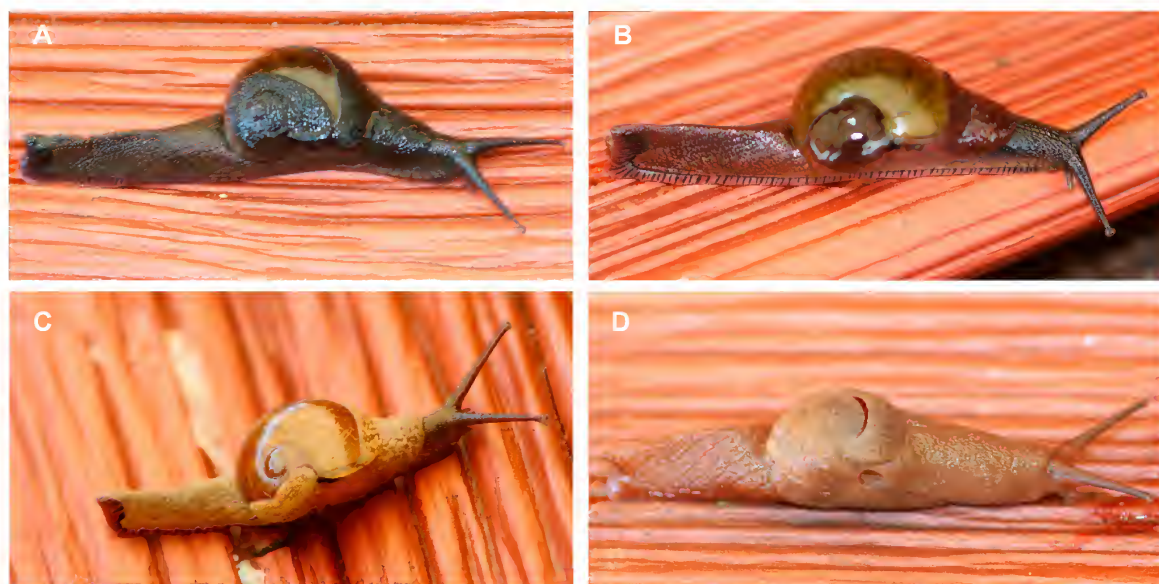


FIG. 6. Eungella semi-slugs. A–C, *Fastosarion comerfordae* sp. nov. A, black form; B, black with red markings form; C, orange-brown form. D, Helicarionid MQ16.

animal length 29.9 mm), than *F. comerfordae* sp. nov. and has a penial chamber with a main pilaster and a background pattern of rounded pustules (Fig. 4F).

The Wet Tropics *F. brazieri* (Cox, 1873) also has a similar central longitudinal pilaster and a background pattern of slender, filamentous pilasters tending to be disposed longitudinally rather than diagonally (Fig. 4G).

DISCUSSION

Fastosarion superba (Cox, 1871) has been known from MEQ since the late 1800s and assumed to inhabit both Mt Dryander (type locality) and Eungella NP based on general animal and shell characters. Scott (1995) was the first to investigate the anatomy of the species and concluded that both populations represented the same species. Consequently but somewhat mistakenly, Scott (1995) figured the genitalia of a specimen from Eungella and the penis interior of a specimen from Mt Dryander. The current study shows that the Eungella population is a separate species based on differences in animal features and penial

anatomy. A single central longitudinal pilaster with a background chevron-like pattern of diagonal lamellae distinguishes *F. superba* and *F. comerfordae* from others currently in the genus (see generic diagnosis above). However, the protoconch sculpture of the two MEQ species is shared with *F. brazieri* from the Wet Tropics.

Also included in Scott's (1995) concept of *F. superba* were specimens from the heights of Mt Macartney (alt. 900 m) located in the Cathu SF, Clarke Range, north of Eungella NP, MEQ. Dissection showed that this species has a background pattern of diamond shaped pustules and a much shorter apical pilaster consisting of aggregated pustules in contrast to the lamellar pattern of both *F. comerfordae* and *F. superba*. The Mt Macartney species most likely belongs in a separate genus.

For identification purposes *F. comerfordae* can be readily distinguished from *F. superba* and other MEQ semi-slugs by the unique black dart-like markings on the sides of the foot below the pedal grooves (Fig. 1). These markings are present even in very juvenile and longterm preserved specimens.

ACKNOWLEDGEMENTS

I would like to sincerely thank Isabel Hyman, Australian Museum (Sydney) for supplying pertinent information and drawings on the anatomy of several semi-slug species relevant to this study, and for our ongoing conversation on the systematics and biogeography eastern Australian semi-slugs. Two anonymous referees are thanked for their supportive comments.

LITERATURE CITED

- Hyman, I.T. & Ponder, W.F. 2010. A morphological phylogenetic analysis and generic revision of the Australian Helicarionidae (Gastropoda: Pulmonata: Stylommatophora) and an assessment of the relationships of the family. *Zootaxa* **2461**: 1-148.
- Hyman, I.T., Lamborena, I. de la I., & Köhler, F. 2017. Molecular phylogenetics and systematic revision of the south-eastern Australian Helicarionidae (Gastropoda, Stylommatophora). *Contributions to Zoology* **86**: 51-95.
- Iredale, T. 1933. Systematic notes on Australian land shells. *Records of the Australian Museum* **19**: 37-59, <https://doi.org/10.3853/j.0067-1975.19.1933.690>.
1937. A basic list of the land Mollusca of Australia. Part II. *Australian Zoologist* **9**: 1-39.
1938. A basic list of land Mollusca of Australia. Part III. *Australian Zoologist* **9**: 83-124.
1941. Guide to the land shells of New South Wales. Part 3. *The Australian Naturalist* **11**: 1-8.
- Scott, B. 1995. Redescription of *Fastosarion superba* (Cox, 1871) with descriptions of two new species of *Fastosarion* from northern Queensland (Pulmonata: Helicarionidae). *Molluscan Research* **16**: 69-80, <https://doi.org/10.1080/13235818.1995.10673667>.
- Smith, B.J. 1992. Non-marine Mollusca. In, Houston, W.W.K. (ed.), *Zoological Catalogue of Australia*. Volume 8. (Australian Government Publishing Service: Canberra). 405pp.
- Stanisic, J. 1993. *Eungarion mcdonaldi* gen. et sp. nov., a montane semi-slug from mideastern Queensland rainforests (Pulmonata: Helicarionidae). *Memoirs of the Queensland Museum* **34**: 27-34.
- Stanisic, J., Shea, M., Potter, D. & Griffiths, O. 2010. *Australian land snails. Volume 1. A field guide to eastern Australian species*. (Bioculture Press: Mauritius). 596pp.

Three new species of *Cladethosoma* Chamberlin, 1920 from southeast Queensland (Diplopoda: Polydesmida: Paradoxosomatidae)

Robert MESIBOV

West Ulverstone, Tasmania 7315, Australia. Email: robert.mesibov@gmail.com

Citation: Mesibov, R. 2018. Three new species of *Cladethosoma* Chamberlin, 1920 from southeast Queensland (Diplopoda: Polydesmida: Paradoxosomatidae). *Memoirs of the Queensland Museum – Nature* 61: 53–67. Brisbane. ISSN 2204-1478 (Online) ISSN 0079-8835 (Print). Accepted: 10 March 2018. First published online: 8 June 2018

<https://doi.org/10.17082/j.2204-1478.61.2018.2018-06>

LSID urn:lsid:zoobank.org:pub:623C65CB-56B7-4246-B8B6-858F74164343

ABSTRACT

The eastern Australian millipede genus *Cladethosoma* Chamberlin, 1920 is represented in Queensland by *C. monticola* sp. nov., *C. musgravei* sp. nov., *C. toowoomba* sp. nov., and *C. uncinatum* Jeekel, 1987. The three new species all occur in the southeast of the State and are likely to be small-range endemics. *C. toowoomba* sp. nov. was first recorded in 2017 as a digital image on BowerBird, an Australian citizen science website. □ *Diplopoda, Polydesmida, Paradoxosomatidae, new species, Queensland, Australia.*

Eight species in the paradoxosomatid genus *Cladethosoma* Chamberlin, 1920 have been described from New South Wales (Mesibov 2006–2018). A Queensland species, *C. uncinatum* Jeekel, 1987, was found by C.A.W. Jeekel in the Naturhistoriska Riksmuseet, Stockholm, Sweden among material collected by Erik Mjöberg during his 1912–13 Queensland expedition (Ferrier 2006).

I sorted another two Queensland *Cladethosoma* species from Australian Museum and Queensland Museum specimens during a Paradoxosomatidae cataloguing project in 2006 and 2007 (Mesibov 2008). A fourth Queensland *Cladethosoma* species was imaged by Toowoomba resident Glenda Walter in October 2017 and the images posted on the Australian citizen science website BowerBird (<http://www.bowerbird.org.au>). Here I describe the three new *Cladethosoma* species and comment on *C. uncinatum*.

MATERIALS AND METHODS

Specimens of the Toowoomba *Cladethosoma* were collected in late 2017 and killed by freezing before posting to the author. All

specimens of new species are stored in 75–80% ethanol in the Australian Museum and the Queensland Museum. Photomicrographs were taken with a Canon EOS 1000D digital SLR camera mounted on a Nikon SMZ800 binocular dissecting microscope equipped with a beam splitter, then manually stacked for processing with Zerene Stacker 1.04 software. Measurements of dissected specimens were made with the same microscope using an eyepiece scale. Gonopods were imaged using an eyepiece video camera mounted on an Amscope binocular microscope after clearing in 80% lactic acid and temporarily mounting in a 1:1 glycerol:water mixture. Preliminary gonopod drawings were traced from printed copies of the images, then corrected by reference to the actual gonopod. The latitude/longitude datum for collection data is WGS84. Gonopod terminology follows Jeekel (1987). Abbreviations: AM = Australian Museum, Sydney; NHRS = Naturhistoriska Riksmuseet, Stockholm, Sweden; Qld = Queensland; QM = Queensland Museum, Brisbane.

SYSTEMATICS

Order Polydesmida Pocock, 1887

Suborder Strongylosomatidea
Brölemann, 1916

Family Paradoxosomatidae Daday, 1889

Subfamily Australiosomatinae
Brölemann, 1916

Tribe Australiosomatini Brölemann, 1916

Cladethosoma* Chamberlin, 1920Australiosoma* (*Cladethosoma*) Chamberlin, 1920: 105. – Attems 1937: 241.*Cladethosoma* Jeekel 1968: 26, 126 [elevated to genus]. – Jeekel 1971: 219. – Jeekel 1979: 649. – Hoffman 1980: 166. – Jeekel 1982a: 141. – Jeekel 1982b: 202. – Jeekel 1984: 20, 32, 37. – Jeekel 1987: 12, 14, 19. – Jeekel 2000: 38, 39. – Rowe & Sierwald 2006: 529, 537. – Jeekel 2006: 79. – Nguyen & Sierwald 2013: 1167.*Leucotessara* Verhoeff, 1928: 87, 90, 92. – Attems 1929: 258. – Attems 1931: 137. – Verhoeff 1932: 1594, 1599. – Attems 1937: 32, 249. – Verhoeff 1937: 134. – Attems 1940: 538. – Verhoeff 1941: 6, 9. – Jeekel 1968: 21, 24, 126. – Jeekel 1971: 226. – Jeekel 1979: 649 [synonymized with *Cladethosoma*]. – Hoffman 1980: 166. – Jeekel 1982a: 141. – Jeekel 1984: 32. – Jeekel 1987: 19. – Rowe & Sierwald 2006: 537. – Jeekel 2006: 79. – Nguyen & Sierwald 2013: 1167.*Hoplatessara* (*Walestessara*) Verhoeff, 1937: 137. – Attems 1940: 547. – Verhoeff 1941: 9.*Walestessara* Jeekel 1968: 24 [elevated to genus and synonymized with *Leucotessara*]. – Jeekel 1979: 649 [as synonym of *Cladethosoma*]. – Hoffman 1980: 166. – Jeekel 1982a: 141. – Jeekel 1984: 32. – Jeekel 1987: 19. – Rowe & Sierwald 2006: 537. – Jeekel 2006: 79. – Nguyen & Sierwald 2013: 1167.**Type species.** *Australiosoma* (*Cladethosoma*) *clarum* Chamberlin, 1920, by monotypy; now accepted as a synonym of *Cladethosoma trilineatum* (Newport, 1844).**Type species of *Leucotessara*.** *Leucotessara lucida* Verhoeff, 1928, by monotypy; now accepted as *C. lucidum* (Verhoeff, 1928).**Type species of *Walestessara*.** *Hoplatessara* (*Walestessara*) *cruciata* Verhoeff, 1937, by monotypy; now accepted as *C. cruciatum* (Verhoeff, 1937).**Included species.** *C. calcaratum* Jeekel, 2006; *C. cruciatum* (Verhoeff, 1937); *C. forceps* (Verhoeff, 1941); *C. (Haplethosoma) gladiator* Jeekel, 1982; *C. inflatum* Jeekel, 1982; *C. lucidum* (Verhoeff, 1928); *C. monticola* sp. nov.; *C. musgravei* sp. nov.; *C. toowoomba* sp. nov.; *C. tortuosum* Jeekel, 2006; *C. trilineatum* (Newport, 1844); *C. uncinatum* Jeekel, 1987.**Remarks.** *Cladethosoma* species can be relatively large (to 4 cm long) and several species are conspicuously patterned. The species most often seen alive is probably *C. trilineatum*, which is common in the Sydney metropolitan area in New South Wales and, as *Strongylosoma trilineata* Newport, 1844, was the second millipede species to be described from Australia. The first described species, *Polydesmus gervaisii* Lucas, 1840, has not been confidently identified and may be a synonym of *C. trilineatum* (Jeekel 2006).In addition to the three new Queensland species described below, another four undescribed *Cladethosoma* species from New South Wales were sorted by C.A. Car (Car 2009) and the author for the 2006–2007 project referred to in the introduction. The four new New South Wales *Cladethosoma* have been deposited as sorted, labelled material in the Australian Museum and Museums Victoria.***Cladethosoma monticola* sp. nov.**

(Figs 1, 2)

Etymology. Latin “montis” + “icola”, mountain-dweller; noun in apposition. This species has so far only been found above 1000 m.**Holotype.** Male (in 2 pieces), Mt Mitchell, Qld, 28°04'S 152°24'E, 1060 m (–28.0610 152.3955 ±500 m), 1 March – 11 April 1992, D. Cook, rainforest, intercept trap, QM S74493.**Paratypes.** 1 male, details as for holotype but 2 December 1991 – 6 January 1992, QM S74495; 1 male, same details but 6 January – 1 March 1992, QM S74494.**Other material examined.** 2 males, Mt Asplenium, Qld, 28°09'S 152°26'E, 1290 m (–28.1565 152.4355 ±100 m), 18–20 December 1992, G. Monteith, QM S74496; 1 male, same details but 20 December 1992 – March 1993, intercept & pitfall traps, QM S74498; 1 male, Mt Huntley, Qld, 28°08'S 152°26'E, 1250 m (–28.1435 152.4320 ±100 m), 29–30 January 1993, G. Monteith, QM S74497; 1 male, Spicers Peak, Qld, summit, 28°06'S 152°24'E, 1200 m (–28.0994 152.4079 ±100 m), 30–31 December 1993, G. Monteith, QM S74499.**Diagnosis.** Distinguished from other *Cladethosoma* species by a combination of (1) a large, rounded, medial notch at the apex of the femoral process, as in *C. inflatum*, but with neither a swelling of the femoral process nor a lateral extension of the solenomere; (2) the medial tibiotarsal process slender and anteriorly

curved and the lateral process broad with an obliquely truncate tip, as in *C. trilineatum*, but with the femoral process more curved apically and with a large, rounded notch.

Description. (Male) Approximate length 27 mm; midbody prozonite width 2.6 mm; midbody width across paranota 3.0 mm. Colour of preserved specimens varies; specimens from type locality (Figs 1A, B, C, G) seemingly etiolated, with head brown, lighter ventrally but frons darkest; antennae light yellowish basally, brown distally; prozonites pale pinkish-brown with darker posterior margin dorsally and faint, thin, mid-dorsal stripe; metazonites with sharply demarcated triangular brown patch on midline, the apex towards head and appearing to be continued as dark area medially at posterior margin of prozonite, triangle sides slightly concave and bordered by pale or light yellowish, oblique, paramedian patches (closest to midline anteriorly); lateral metatergite margins and posterior portion of body ring darker, brownish; the pattern of dark midline patch, lighter paramedian areas and darker lateral margins also on collum, haplosegments and preanal ring; paranota, legs and waist pale or light yellowish. Specimens from Mt Asplenium (Fig. 1D), Mt Huntley and Spicers Peak with body rings more uniformly dark brown, but mid-dorsal “triangle” still apparent.

Head (Fig. 1A) with vertex bare, frons and clypeus moderately setose; post-antennal groove lightly impressed; vertigial sulcus distinct, extending just past level of antenna sockets; sockets separated by ca 1.1x socket diameter. Antennae filiform, extending when manipulated to rear of ring 3; relative antennomere lengths (3=4=5) > (2=6); antennomere 6 widest. Head a little wider than collum and ring 2; ring widths 6-16 > 5 > (4=2) > 3; widths decreasing on rings 17-19. Collum from above with anterior and posterior margins medially straight, parallel; anterior margin gently convex laterally, corners broadly rounded. Ring 2 corner below corners of collum and ring 3. Pleural keel a thin, indistinct ridge on rings 2-4. Diplosegments (Figs 1B-D) with waist not strongly constricted; prozonite and metazonite bare with indistinct cellular

sculpture, waist with indistinct longitudinal ridging dorsally, ridges absent laterally and ventrally; transverse furrow distinct, extending laterally not quite as far as paranotal bases; limbus a thin, continuous sheet. Paranota at ca 1/2 ring height, thin, narrow, tapering distally to bluntly rounded posterior corner not extending past posterior margin of metatergite on any rings, dorsally with shallow excavation. Pore formula normal; ozopore small, round, opening laterally on paranotum at ca 1/4 paranotal length from posterior corner. Spiracles on diplosegments well-separated, opening just above and slightly anterior to leg bases; spiracular openings ovoid; spiracular filters slightly emergent, anterodorsal portion of anterior spiracular filter folded posteriorly, filter of posterior spiracle shaped like inverted “U”. Sternites slightly wider than long, sparsely setose, cross-furrows very weakly impressed, no cones on any sternite. Midbody legs slender, length ca 1.7x midbody diameter, relative podomere lengths femur > tarsus > (prefemur=tibia) > postfemur; femur 1.1x as long as tarsus; prefemora only a little swollen dorsally on anterior legs. Epiproct (Fig. 1G) extending past anal valves, in dorsal view tapering to truncated tip ca 1/5 maximum width of preanal ring; hypoproct paraboloid; spinnerets in square array.

Male leg 1 (Fig. 1E) with short hook-shaped ventral femoral process. Gonopore small, opening on distomedial bulge of leg 2 coxa. Dense brush setae on tarsi of legs 2-6. Sternal lamella (Fig. 1F) paraboloid in posterior view, at base ca 80% of width between leg 4 bases, anterodistally with dense short setation. Gonopod aperture ca 1/3 width of ring 7 prozonite. Gonopods (Fig. 2) reaching to legs 6; ring 6 sternite slightly excavate between leg 7 bases. Gonocoxa short, wide at base and tapering distally, slightly bent ventrally in middle, densely setose on anterior surface; cannula prominent. Telopodites with small, posteriorly setose prefemoral portion demarcated from acropodite by slight ridging. Acropodite expanding from base, divided at ca 1/3 telopodite height into femoral process (fp) laterally, solenomere (so) centrally and two tibiotarsal processes medially. Femoral process

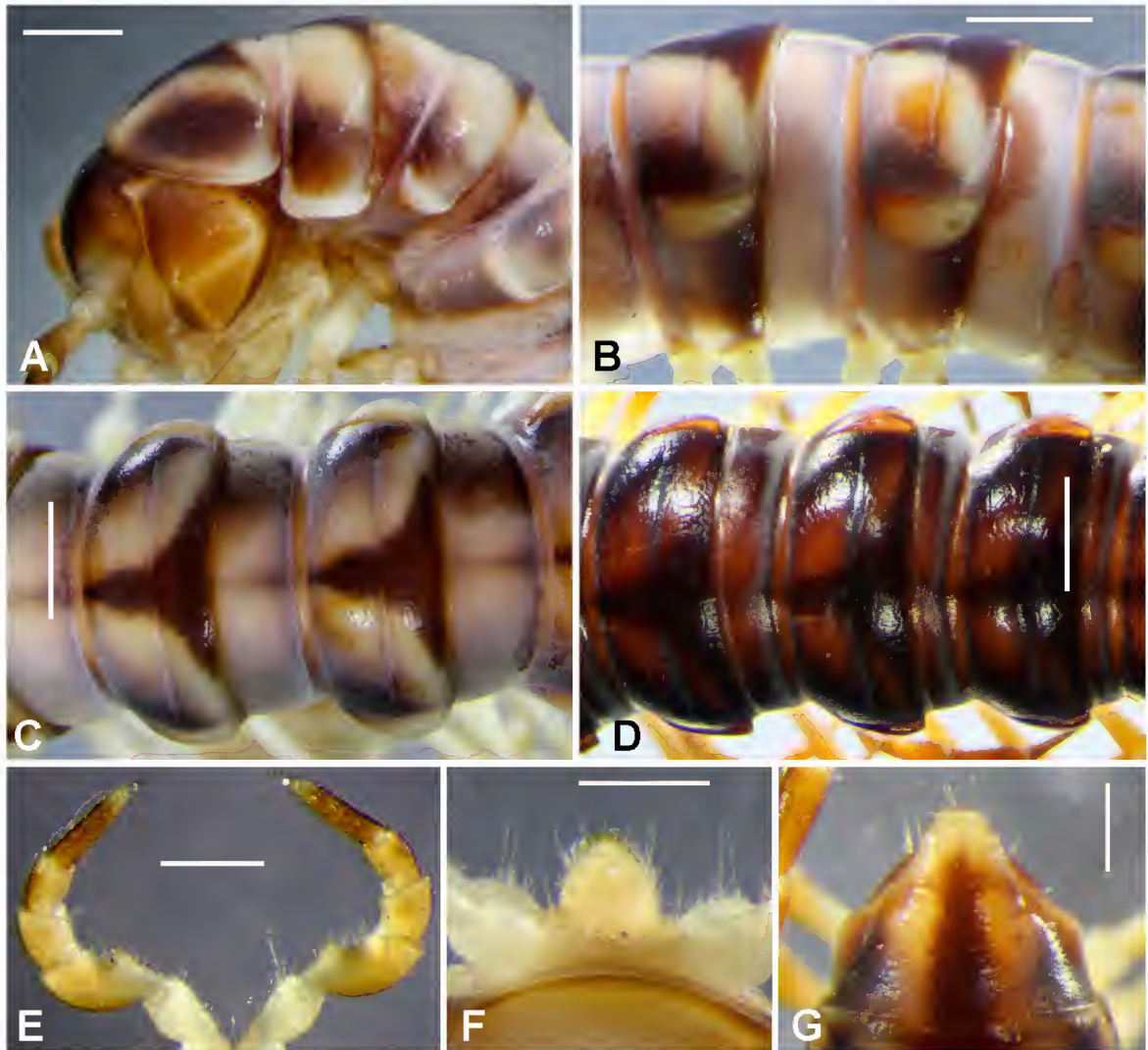


FIG. 1. *Cladethosoma monticola* sp. nov. Holotype male (A, B, C), QM S74493; male ex QM S74496 (D); paratype male, QM S74495 (E, F); paratype male, QM S74494 (G). A, left lateral view of head and anterior rings; B, lateral view of midbody rings (right-left reversed for consistency with Fig. 1C); C, D, dorsal views of midbody rings; E, anterior view of dissected legpair 1; F, posterior view of sternal lamella; G, dorsal view of telson. Scale bars: A-D = 1.0 mm, E-G = 0.5 mm.

a little inflated anteroposteriorly and greatly expanded distally, the distal margin broadly curved with acuminate tip directed medially, the tip crossing the trunk midline; large, rounded, medial notch basal to the tip formed by subtriangular projection. Solenomere nearly as wide as femoral process at base, curving laterally just above base, then medially at ca

1/2 height, the outer (lateral) margin with a rounded laminate extension, the apex thin, a little expanded and truncate distomedially, almost reaching top of femoral process. Medial tibiotarsal process (mtp) slender, bluntly pointed, curved anteriorly and slightly laterally. Lateral tibiotarsal process (ltp) more or less erect, longer than medial tibiotarsal process but not reaching

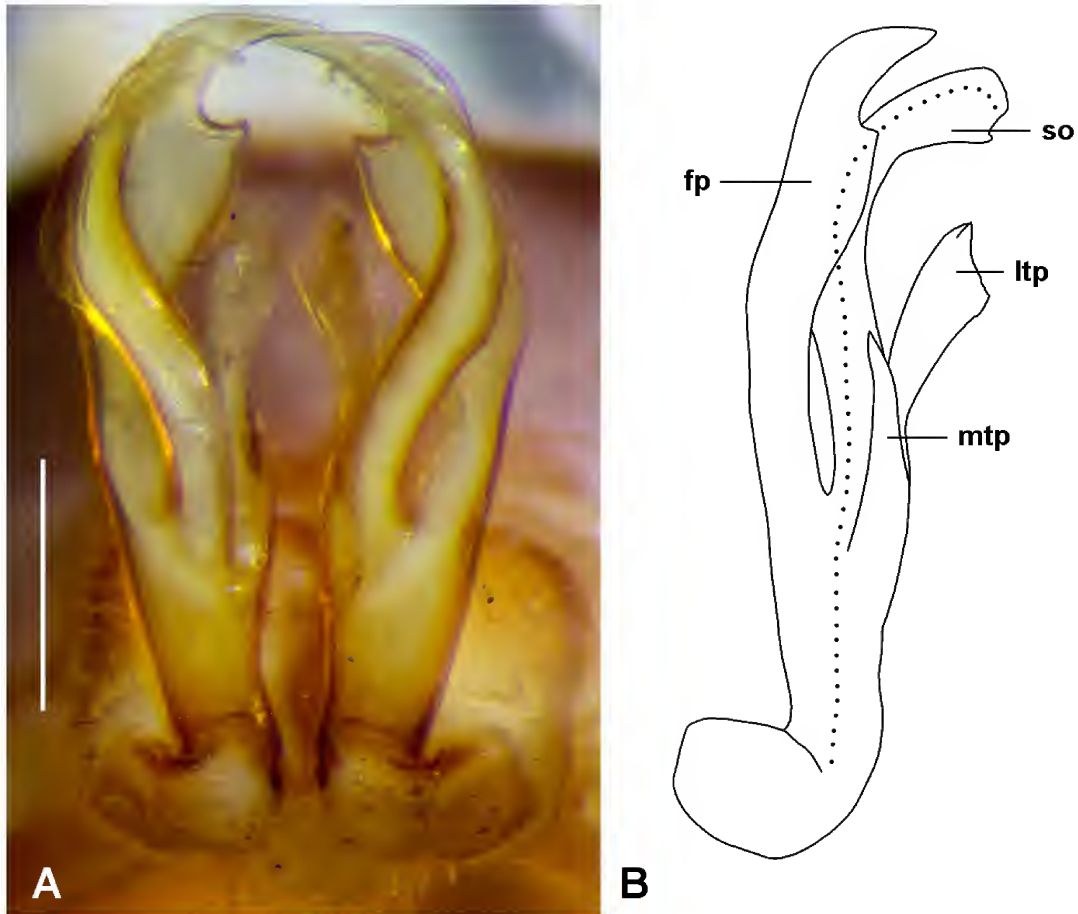


FIG. 2. *Cladethosoma monticola* sp. nov., paratype male, QM S74494. A, posterior view of gonopods *in situ* on dissected ring 7; scale bar = 0.5 mm. B, anterior and slightly medial view of left gonopod. Dotted line in B indicates course of prostatic groove; setation on prefemoral portion not shown. fp = femoral process, ltp = lateral tibiotarsal process, mtp = medial tibiotarsal process, so = solenomere.

level of femoral process notch, curving slightly medially from base and expanded distally, as wide as solenomere at obliquely truncate apex. Prostatic groove running on anteromedial surface of solenomere and terminating medially a little below distal margin of solenomere tip.

Female not yet known.

Distribution. Mountains in the Main Range, ca 35 km ENE of Warwick in southeast Queensland

(Fig. 3). The known range has a linear extent of ca 15 km.

Remarks. Latitude/longitude figures in decimal degrees with estimated uncertainties were obtained using the Queensland Government's digital mapping portal, "Queensland Globe" (<https://qldglobe.information.qld.gov.au/>; accessed 3 February 2018).

The relative width of the lateral tibiotarsal process varies a little in this species; the widest tip is in the type specimens.

Cladethosoma musgravei sp. nov.

(Figs 4, 5)

Etymology. For the Queensland-born entomologist Anthony Musgrave (1895–1959), who collected all the known specimens.

Holotype. Male, Macpherson Ranges National Park, Qld [$-28.2310\ 153.1360 \pm 1$ km; see Remarks], 15 December 1926, A. Musgrave, AM KS.128099 (ex AM KS.94134).

Paratypes. 1 male, 2 females, details as for holotype, AM KS.94110; 1 male, 1 female, same details, AM KS.94133; 1 male, 1 female, same details, AM KS.94134; 1 male, 1 female, same details, AM KS.94137; 1 male, 1 female, same details, AM KS.94138; 1 male, same details but 19 December 1926, AM KS.94157.

Other material examined. 1 male, Mt Tamborine, Qld [$-27.9690\ 153.1980 \pm 5$ km], December 1925, A. Musgrave, AM KS.94163.

Diagnosis. Distinguished from other *Cladethosoma* species in having the solenomere longer than the femoral process and with the tibiotarsal processes apparently reduced to two small branches on the anteromedial surface of the solenomere.

Description. Male/female approximate length 26/28 mm; midbody prozonite width 2.6/3.7 mm; midbody width across paranota 3.0/4.0 mm. After long preservation in alcohol, specimens almost uniformly light brown with pale yellow legs and paranota.

Male. head (Fig. 4A) with vertex bare, frons and clypeus sparsely setose; post-antennal groove lightly impressed; vertigial sulcus distinct, extending to level of antenna sockets; sockets separated by ca 1.5x socket diameter; cardines and stipetes distinctly bulging (Fig. 4B). Antennae (Fig. 4A) filiform, extending when manipulated to rear of ring 3; relative antennomere lengths $2 > (3=4=5=6)$; antennomere 6 widest. Head with bulging “cheeks” distinctly wider than collum (Fig. 4B); widths of collum and rings 2–4 subequal < ring 5 < rings 6–16 > rings 18 and 19. Collum from above (Fig. 4B) half moon-shaped, posterior margin slightly concave, corners broadly rounded; ring 2 corner below corners of collum and ring 3. Pleural keels represented by low, rounded ridges on rings 2–5. Diplosegments (Figs 4C, D) with strongly constricted waist;

prozonite and metazonite bare, waist with faint longitudinal ridges; transverse furrow deeply impressed, extending laterally not quite as far as paranotal bases; limbus a thin, continuous sheet. Paranota at ca 1/2 ring height, very narrow, tapering distally to bluntly rounded posterior corner not extending past posterior margin of metatergite on any rings, paranota on non-poriferous rings clearly smaller than on poriferous rings, paranota on rings 18 and 19 very small. Pore formula normal; ozopore small, round, opening laterally on paranotum at ca 1/4 paranotal length from posterior corner. Spiracles on diplosegments well-separated, opening just above and slightly anterior to leg bases; spiracular openings ovoid; spiracular filters slightly emergent, anterodorsal portion of anterior spiracular filter folded posteriorly, filter of posterior spiracle shaped like inverted “U”. Sternites about as wide as long, sparsely setose, cross-furrows weakly impressed, transverse furrow slightly deeper; no cones or other processes on any sternite. Midbody legs slender, length ca 2x ring diameter, relative podomere lengths tarsus > femur > tibia > (prefemur=postfemur); femur 0.9x as long as tarsus; prefemora slightly swollen dorsally, more so on anterior legs. Epiproct (Figs 4E, F) extending past anal valves, in dorsal view tapering to truncated tip ca 1/6 maximum width of preanal ring; hypoproct paraboloid; spinnerets in square array.

Male leg 1 (Fig. 4H) with short, inconspicuous ventral femoral process. Gonopore small, opening distomedially on leg 2 coxa. Dense brush setae on tarsi of legpairs 1–6 only. Width of sternal lamella (Fig. 4G) less than 1/2 width of gap between leg 4 bases, lateral margins subparallel, ventral margin gently convex, lamella anterodistally with dense short setation. Gonopod aperture ca 1/3 width of ring 7 prozonite. Gonopod telopodites (Fig. 5A) reaching to legs 7; ring 6 sternite only slightly excavate between leg 7 bases. Gonocoxa short, subcylindrical with anteromedial setation; cannula prominent. Telopodites (Figs 5B–D) with small, posteromedially setose prefemoral portion (pf) demarcated from acropodite by slight ridging. Acropodite narrower than

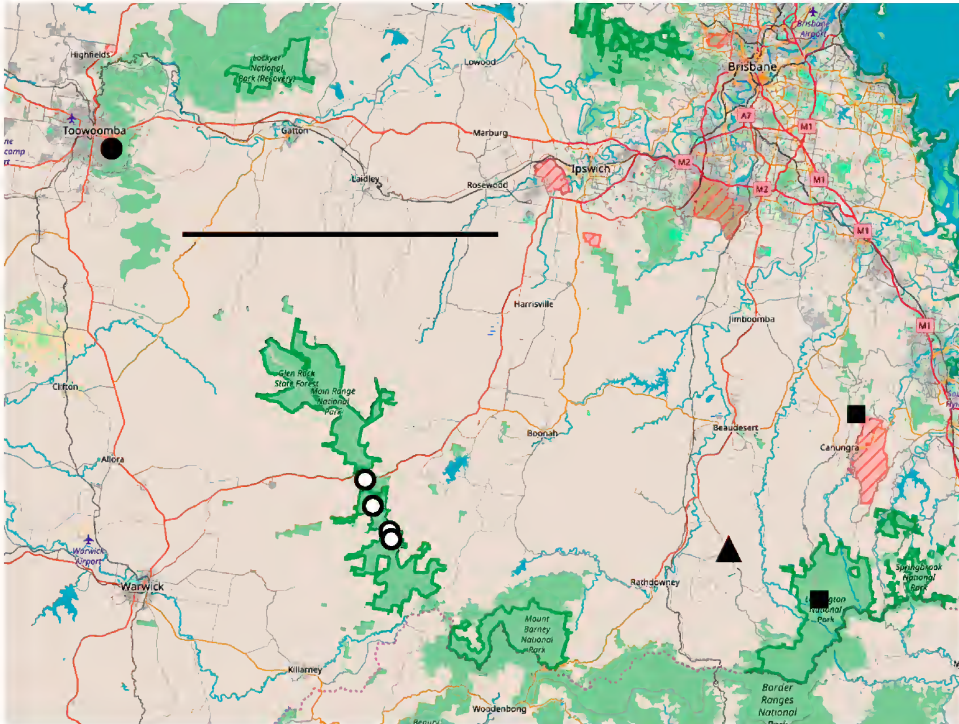


FIG. 3. Known localities as of 1 February 2018 for *Cladethosoma monticola* sp. nov. (open circles), *C. musgravei* sp. nov. (squares), *C. toowoomba* sp. nov. (filled circle) and *C. uncinatum* Jeekel, 1987 (triangle) in southeast Queensland. Scale bar = 50 km; base map from Open Street Map project (<https://www.openstreetmap.org>).

prefemoral portion at base, abruptly expanding laterally and divided at ca 1/3 telopodite height into medial solenomere (so) and lateral femoral process (fp). Solenomere and femoral process both anteroposteriorly flattened and erect. Femoral process gently curving medially, distal third deeply excavate medially, the narrow tip bluntly rounded and crossing the midline; distal half close to and parallel to solenomere (in Fig. 5B the femoral process has been displaced anteriorly for clarity). Solenomere longer than femoral process, bent slightly laterally at base, then sharply curving medially, slightly wider at midlength, the apex thin, slightly expanded and medially truncate. Erect, narrow solenomere process (sp1) arising from anteromedial surface of solenomere at ca 1/2 telopodite height (above division between solenomere and femoral process), apex acute, with small, bluntly acuminate subprocess (sp2) arising from anterior surface of solenomere

process (sp1) and terminating at ca 1/2 process height. Prostatic groove running on anteromedial surface of solenomere and terminating medially on thickened distal margin of solenomere tip.

Female less slender than male but with legs more slender and only 1.3x midbody diameter in length; anterior margin of ring 3 not produced ventrally as an epigyne; cyphopods not examined.

Distribution. Lamington Plateau and Mt Tamborine in southeast Queensland (Fig. 3). The two known localities are ca 30 km apart.

Remarks. I place this species in *Cladethosoma* because I see it is a highly derived member of the genus. The solenomere has grown in development relative to the femoral process and has “absorbed” the tibiotarsal processes. Instead of being paired acropodite branches arising at or below the level of the solenomere/femoral

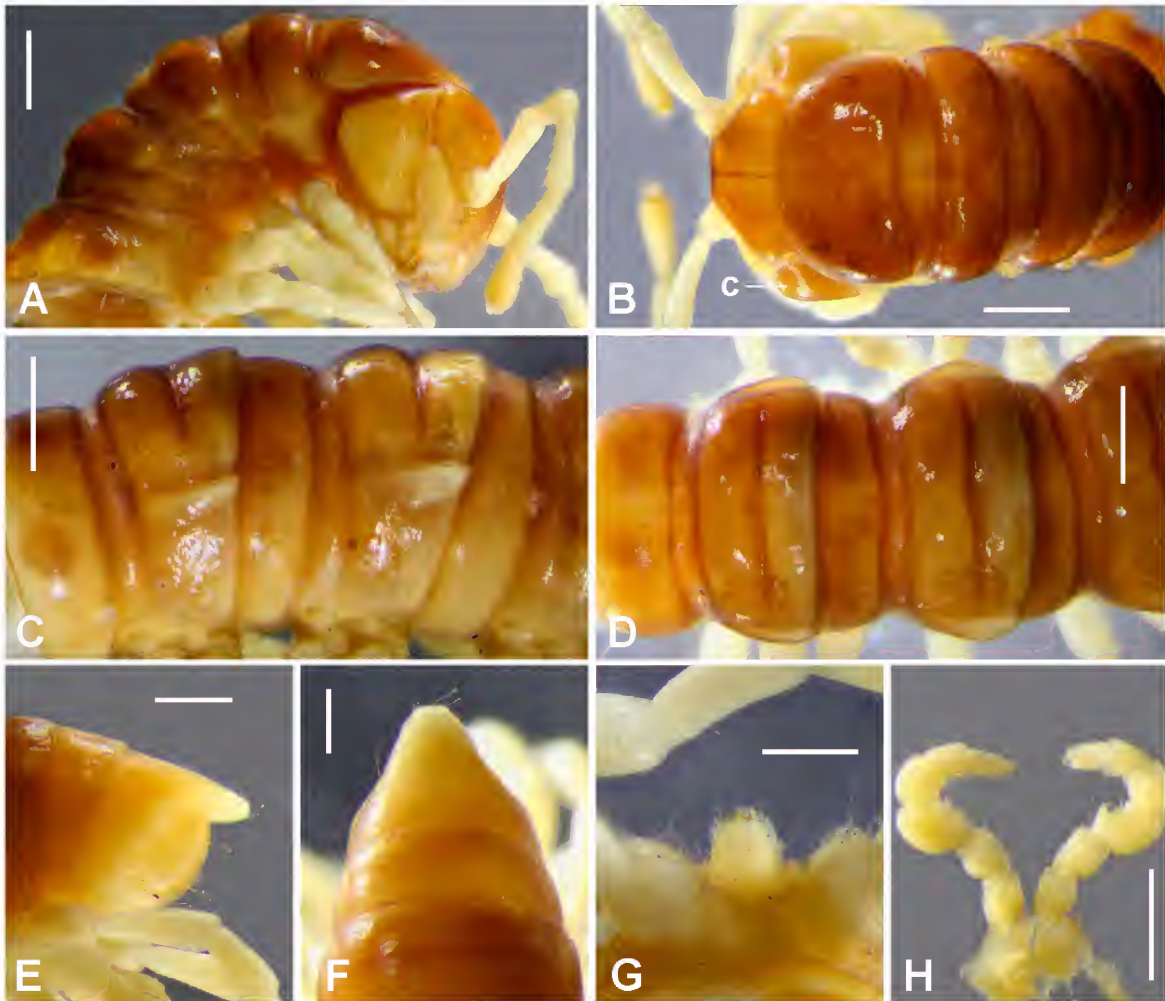


FIG. 4. *Cladethosoma musgravei* sp. nov., male paratypes ex AM KS.94137 (A, B) and AM KS.94134 (C-H). A, right lateral view of head and anterior rings; B, dorsal view of head with left cardo indicated (c); C, left lateral view of midbody rings; D, dorsal view of midbody rings; E, left lateral view of telson; F, dorsal view of telson; G, posterior view of sternal lamella; H, anterior view of dissected legpair 1. Scale bars: A-E, H = 1.0 mm, F, G = 0.5 mm.

process split, the tibiotarsal processes appear to have been reduced to a conjoined pair of small solenomere branches. These are here called "solenomere process 1" and "solenomere process 2" because I am reluctant to guess their homological assignments to the median and lateral tibiotarsal processes, respectively.

Musgrave (1928) wrote an illustrated account for the *Australian Museum Magazine* of his expedition with P.A. Gilbert to the Macpherson

Range, 14-26 December 1926. During the first week of the trip, the collectors were confined to the area around the recently opened O'Reilly guesthouse due to heavy rain. "From this haven of refuge we made our excursions into the jungle to observe the birds, and to collect insects. Despite the fact that the rain forced us to remain indoors for the greater part of our stay, I was able to bring away about 500 insects for the Museum collection" (Musgrave 1928:

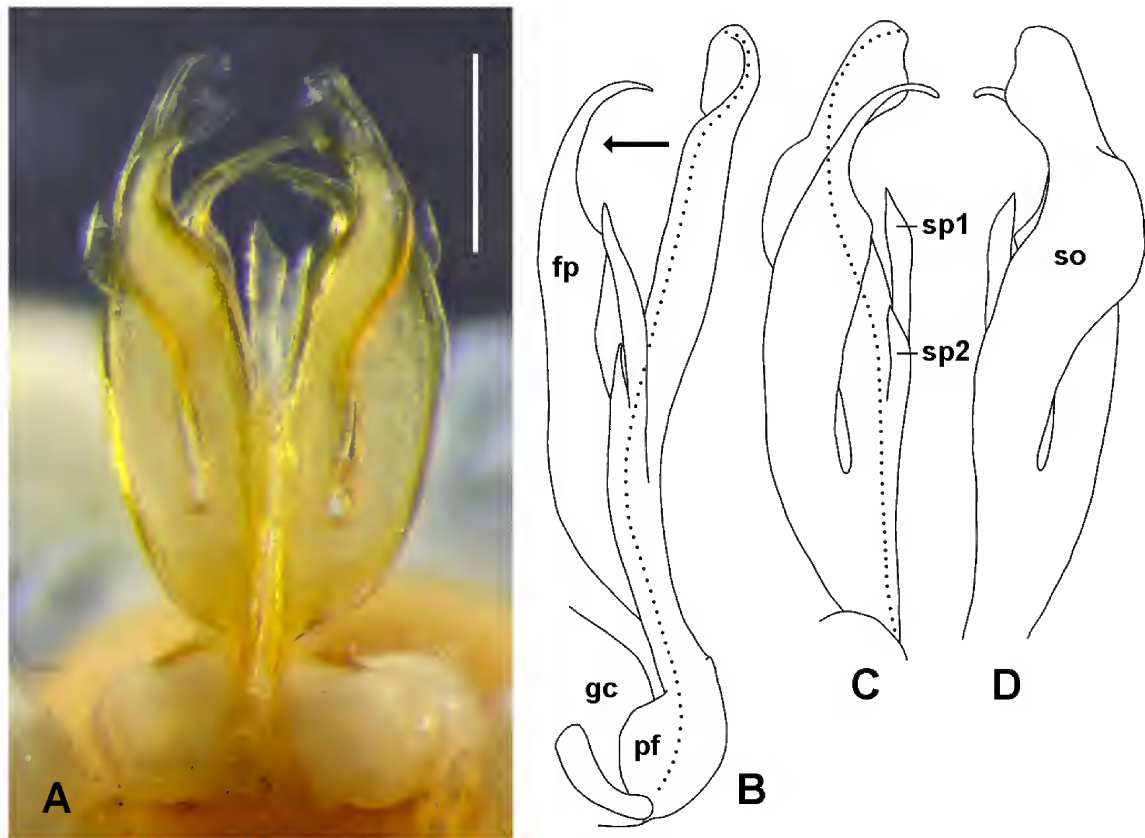


FIG. 5. *Cladethosoma musgravei* sp. nov., male paratypes ex AM KS.94134 (A) and AM KS.94133 (B-D). A, posterior view of gonopods in situ; scale bar = 0.5 mm; B, medial view of left gonopod with femoral process (fp) displaced anteriorly in specimen for clarity, as indicated by arrow; C, anterior and slightly lateral view of left gonopod; D, posterior and slightly medial view of left gonopod. Dotted lines in B and D indicate course of prostatic groove; setation on prefemoral portion not shown in B. fp = femoral process, gc = gonocoxa, pf = prefemoral portion, so = solenomere, sp1 = solenomere process 1, sp2 = solenomere process 2.

175). On this evidence, the type locality is the area around what is now O'Reilly's Rainforest Retreat, on private property on the Lamington Plateau. Musgrave (1926) also published an illustrated article describing his 1924 and 1925 collecting trips to Mt Tamborine, but the text offers no clues to the location of his millipede collecting site.

It is curious that no specimens of *C. musgravei* sp. nov. are in the Queensland Museum, since Mt Tamborine and the area around O'Reilly's accommodation have often been visited by Queensland collectors over the past 90 years. The long legs and bulging "cheeks" in the male

should make this species readily recognisable in the field in future.

***Cladethosoma toowoomba* sp. nov.**
(Figs 6, 7, 8)

Etymology. For the city containing the type locality; noun in apposition.

Holotype. Male, Hartmann Bushland Reserve, Rangeville, Toowoomba, Qld, -27.5901 151.9860 ±25 m, 21 December 2017, G. Walter and M. Rooke, on tree trunk at night after rain, QM S108444.

Paratypes. 7 males, 2 females, details as for holotype, QM S108445; 1 juvenile male, same locality but -27.5901 151.9861 ±25 m (UTM from GPS 56J 0399938 6947788) 12 October 2017, C. Reid, on stem of *Breynia oblongifolia*,

QM S108446; 1 male (gonopods damaged), same locality and collector but -27.5903 151.9861 ±25 m (UTM from GPS 56J 0399933 6947773), 30 November 2017, QM S108447.

Other material. None known.

Diagnosis. Distinguished from other *Cladethosoma* species in having a massive, somewhat inflated femoral process and the medial tibiotarsal process much larger than the lateral process.

Description. Male/female approximate length 45/38 mm; midbody prozonite width 4.8/4.9 mm; midbody width across paranota 5.5/5.3 mm. Live and freshly preserved specimens (Fig. 6) dark brown with wide paramedian pale or light yellow patches, widest posteriorly, on collum and all body rings, including pre-anal ring; head dark brown with post-antennal groove, labrum and mouthpart margins light; antennae light brown basally, darker distally; paranota and waist light; legs brown, paler ventrally.

Male. Head (Fig. 6B) with vertex bare, frons and clypeus sparsely setose; post-antennal groove lightly impressed; vertigial sulcus faint, extending to level of antenna sockets; sockets separated by ca 1.25x socket diameter. Antennae filiform, extending when manipulated to rear of ring 3; relative antennomere lengths (2=3) > (4=5) > 6; antennomere 6 widest. Ring 2 distinctly wider than collum and ring 3, collum wider than head; ring widths slightly increasing posteriorly to ca ring 6, decreasing on rings 18 and 19. Collum from above rounded-trapezoidal, corners broadly rounded; ring 2 corner below corners of collum and ring 3. Pleural keels represented by low, indistinct swellings on anterior rings. Diplosegments (Figs 6D, E) with waist not strongly constricted; prozonite and metazonite bare with indistinct cellular sculpture, waist with indistinct longitudinal ridging dorsally, ridges absent laterally and ventrally; transverse furrow distinct, extending laterally not quite as far as paranotal bases; limbus a thin, continuous sheet. Paranota at ca 1/2 ring height, thin, narrow, tapering distally to bluntly rounded posterior corner not extending past posterior margin of metatergite on any rings, dorsally

with shallow excavation. Pore formula normal; ozopore small, round, opening laterally on paranotum at ca 1/4 paranotal length from posterior corner. Spiracles on diplosegments well-separated, opening just above and slightly anterior to leg bases; spiracular openings ovoid; spiracular filters slightly emergent, anterodorsal portion of anterior spiracular filter folded posteriorly, filter of posterior spiracle shaped like inverted "U". Sternites slightly wider than long, sparsely setose, cross-furrows weakly impressed, no cones on any sternite but leg sockets somewhat thickened ventrally. Midbody legs slender, length ca 1.3x midbody diameter, relative podomere lengths femur > tarsus > (prefemur=postfemur=tibia); femur 1.6x as long as tarsus; prefemora slightly swollen dorsally. Epiproct (Fig. 6C) extending past anal valves, in dorsal view tapering to truncated tip ca 1/10 maximum width of preanal ring; hypoproct paraboloid; spinnerets in square array.

Male leg 1 (Fig. 7A) with short hook-shaped ventral femoral process. Gonopore small, opening distomedially on small flattened portion of leg 2 coxa. Dense brush setae on tarsi of all legs except leg 1 and last pair, on anterior legs with brush setae also distally on tibiae. Distomedial bulge on leg coxae beginning on leg 6 (Fig. 7C), most pronounced on legs 6 and 7. Sternal lamella (Fig. 7B) filling gap between leg 4 bases, lateral margins very slightly tapering inwards, ventral margin a wide "V", lamella anterodistally with dense short setation. Gonopod aperture ca 1/3 width of ring 7 prozonite. Gonopods (Fig. 8A) reaching to legs 7; ring 6 sternite slightly excavate between leg 7 bases. Gonocoxa short, subcylindrical with sparse setation; cannula prominent. Telopodites (Fig. 8) with small, posteromedially setose prefemoral portion (pf) very faintly demarcated from acropodite by slight ridging. Acropodite expanding from base, divided at ca 1/3 telopodite height into femoral process (fp) laterally, more slender solenomere (so) centrally and two tibiotarsal processes medially. Femoral process longer than solenomere, a little inflated anteroposteriorly and greatly expanded distally, the distal margin broadly curved with acuminate tip directed

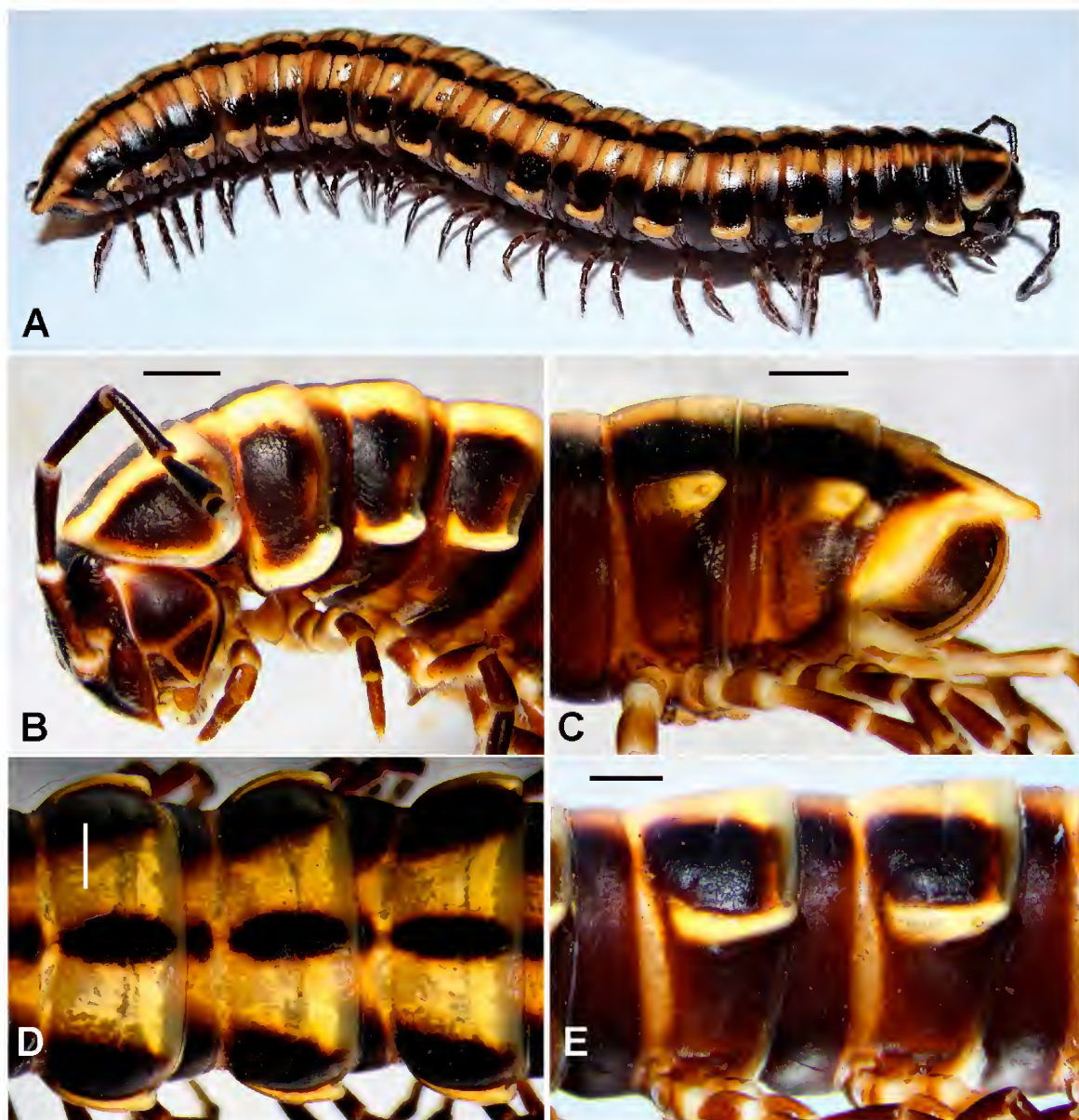


FIG. 6. *Cladethosoma toowoomba* sp. nov. A, live female from type locality imaged by G. Walter on 7 October 2017, length ca 4 cm; B, D, E male holotype, QM S108444; C, male paratype ex QM S108445; B, left lateral view of head and anterior rings; C, left lateral view of telson; D, dorsal view of midbody rings; E, left lateral view of midbody rings. Scale bars: B-E = 1.0 mm.

basally and medially, the tip crossing the trunk midline; small elliptical notch basal to the tip formed by subapical, subtriangular projection; low bulbous swelling on posterolateral surface of femoral process at ca 1/3 process height.

Solenomere erect, nearly as wide as femoral process at base, lower half slightly swollen, distal half flattening anteroposteriorly, curving medially, the apex thin, a little expanded and truncate medially, not quite reaching notch

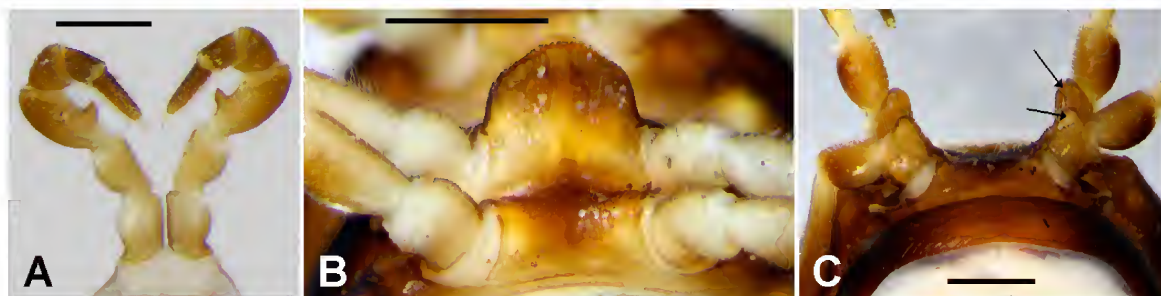


FIG. 7. *Cladethosoma toowoomba* sp. nov., male paratype ex QM S108445. A, anterior view of dissected legpair 1; B, posterior view of sternal lamella. C, anterior view of ring 6 showing distomedial bulges (arrows) on coxae of right legs 6 and 7. Scale bars: 1.0 mm.

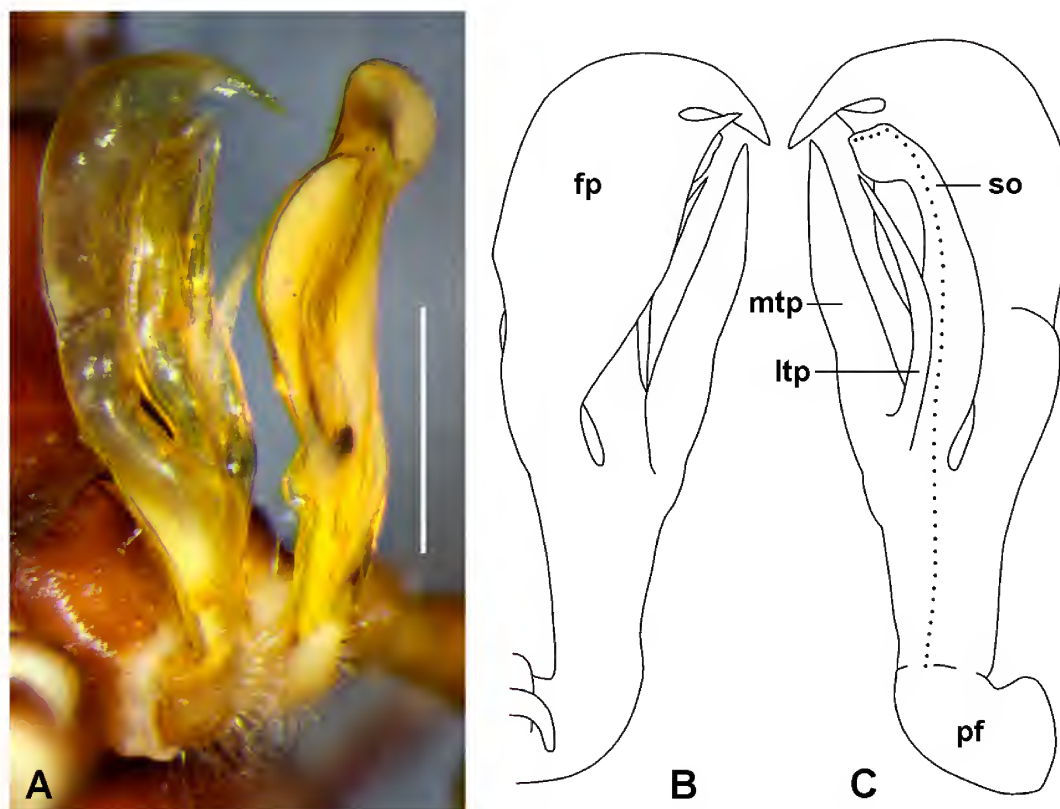


FIG. 8. *Cladethosoma toowoomba* sp. nov., male paratypes ex QM S108445. A, right posterolateral view of gonopods in situ; scale bar = 1 mm. B, anterior and slightly medial view of left gonopod; C, posterior and slightly lateral view of left gonopod. Dotted line in C indicates course of prostatic groove; setation on prefemoral portion not shown in B or C. fp = femoral process, ltp = lateral tibiotarsal process, mtp = medial tibiotarsal process, pf = prefemoral portion, so = solenomere.

on femoral process. Medial tibiotarsal process (**mtp**) nearly as long and wide as solenomere, bent medially and tapering gradually in distal half to bluntly rounded point. Lateral tibiotarsal process (**ltp**) arising just posterior to junction of solenomere and medial tibiotarsal process, slender, pointed, gently curving posteromedially. Prostatic groove running on anteromedial surface of solenomere and terminating medially on thickened distal margin of solenomere tip.

Female shorter than male with relatively shorter and more slender legs; anterior margin of ring 3 not produced ventrally as an epigyne; cyphopods not examined.

Distribution. So far known only from Toowoomba, Queensland (Fig. 3; see Remarks).

Remarks. A live female of this species on a small eucalypt stem at the type locality was imaged by Glenda Walter on 2 October 2017, and the images posted on the BowerBird citizen science website (<http://www.bowerbird.org.au/observations/96035>; accessed 31 January 2018). I requested male specimens from Walter and from my friend Craig Reid, a retired zoologist living not far from Toowoomba. Walter and Reid searched for millipedes with the distinctive colouration of this species in the Hartmann Bushland Reserve on several occasions over the next two months, but found only females. Millipedes were most obvious after sunset during or just after a spell of rainy weather.

Walter reported that the 21 December males and females “were crawling on tree trunks although one may have been at the base of a tree. They seemed to prefer the large conifers planted along the dividing fence by the Hartmann family a century ago, and we haven’t found them anywhere else in the Reserve which is several hectares in area” (G. Walter, *in litt.* 10 January 2018). Large populations of Australian millipedes in exotic conifer litter have been documented in the Australian Capital Territory by Elliott (1971), in Tasmania by the author (Mesibov 2005) and in New South Wales by Car (2010); *C. toowoomba* sp. nov. may occur in conifer plantings elsewhere in the city of Toowoomba.

At lower abundance, it seems likely to be found in future in the escarpment bush reserves just east and south of the type locality, namely McKnight Park, Duggan Bushland and Culliford Drive Park.

***Cladethosoma uncinatum* Jeekel, 1987**
(Fig. 9)

Cladethosoma uncinatum Jeekel, 1987: 20, figs 3, 4. – Jeekel 2006: 80. – Nguyen & Sierwald: 1169.

Holotype. Male, Christmas Creek [–28.1660 152.9870 ±5 km], Qld, [9–11 November] 1912, E. Mjöberg, NHRS (not examined).

Paratypes. 2 males, 1 stadium VII male, 2 stadium VII females, details as for holotype, NHRS (not examined).

Other material. None known.

Remarks. The description of this species does not agree with the illustration of its gonopod. Jeekel (1987, p. 23) wrote: “Tibiotarsal branches very differently developed: the medial branch distinctly shorter than the lateral, and very slender”. In Jeekel’s drawing (fig. 4, here reproduced as Fig. 9) the lateral branch is short, very slender and erect, while the medial branch is tall, stout, twisted from its base and curved anterolaterally, so that its tip lies anterior to the solenomere.

I had hoped to understand this disagreement by examining *Cladethosoma* specimens from across southeast Queensland, but as described above, three entirely different *Cladethosoma* species have been collected in this region. I also examined three specimen lots in AM provisionally identified as *C. uncinatum* (KS.13760, KS.75198 and KS.94104). These are from New South Wales, far to the south of the *C. uncinatum* type locality (the closest is ca 200 km distant), and only superficially resemble *C. uncinatum*. Two may be *C. trilineatum* variants and one may be a new *Cladethosoma* species. Re-examination of the *C. uncinatum* types and further collecting in the Queensland/New South Wales border region will help to clarify the identity of Jeekel’s species.

Although Jeekel (1987, p. 20) gives the collection date for the *C. uncinatum* type material as “X. 1912”, Ferrier (*in litt.*, 16 December 2013) quotes Mjöberg’s field diaries as placing the

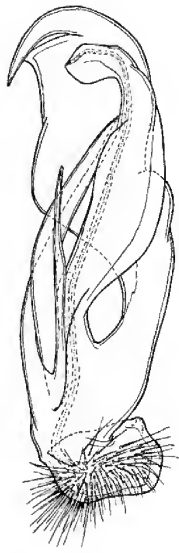


FIG. 9. *Cladethosoma uncinatum* Jeekel, 1987, posterior view of left gonopod, modified (de-stippled) from fig. 4 in Jeekel (1987).

collector in Brisbane and “Mt Tamborine” in October 1912. For 9 November 1912 Mjöberg wrote “Beaudessert [sic] - then train to Christmas Creek - Taboola [sic]” and on 11 November Mjöberg travelled to the Lamington Plateau before returning to Brisbane on 17 November with his Christmas Creek and Lamington Plateau collections. Christmas Creek and Taboola are ca 15 km south of Beaudesert on the now-abandoned Beaudesert Shire Tramway line (https://en.wikipedia.org/wiki/Beaudesert_Shire_Tramway; accessed 1 January 2018). The Christmas Creek tramway station is marked as the *C. uncinatum* locality in Fig. 3.

ACKNOWLEDGEMENTS

I am very grateful to Glenda Walter and Craig Reid for their diligent searching for *C. toowoomba* sp. nov. in October, November and December 2017, and to Åsa Ferrier for travel details from Erik Mjöberg’s unpublished diaries. I thank Owen Seeman (QM) and Graham Milledge (AM) for loans and registration of specimens, and reviewers Sergei Golovatch and Catherine Car for helpful comments on the draft manuscript.

LITERATURE CITED

- Attems, C. 1929. Diplopoden des Belgischen Congo. I. Polydesmoidea. *Revue de zoologie et de botanique africaines* 17(3): 253-378.
1931. Die Familie Leptodesmidae und andere Polydesmiden. *Zoologica (Stuttgart)* 30(3/4): 1-150.
1937. Myriapoda. 3. Polydesmoidea. I. Fam. Strongylosomidae. Pp. i-xxii, 1-300 in *Das Tierreich* 68. (Walter de Gruyter and Co.: Berlin)
1940. Myriapoda. 3. Polydesmoidea. III. Fam. Polydesmidae, Vanhoeffeniidae, Cryptodesmidae, Oniscodesmidae, Sphaerotrachopidae, Peridontodesmidae, Rhachidesmidae, Macellophidae, Pandiodesmidae. Pp. i-xxxii, 1-577 in *Das Tierreich* 70. (Walter de Gruyter and Co.: Berlin)
- Car, C.A. 2009. Keeled millipedes (Diplopoda: Polydesmida: Paradoxosomatidae) in New South Wales. *General and Applied Entomology* 38: 1-8.
2010. Pine plantations and native millipedes (Diplopoda: Polydesmida: Paradoxosomatidae) in south-eastern New South Wales, Australia. *Australian Journal of Entomology* 49(4): 317-323. (<https://dx.doi.org/10.1111/j.1440-6055.2010.00771.x>)
- Chamberlin, R.V. 1920. The Myriapoda of the Australian region. *Bulletin of the Museum of Comparative Zoology* 64(1): 1-269. (Available online: <https://biodiversitylibrary.org/page/30743608>)
- Elliot, H.J. 1971. The role of millipedes in the decomposition of *Pinus radiata* litter in the Australian Capital Territory. *Australian Forest Research* 4: 3-10.
- Ferrier, Å. 2006. Dr Eric Mjöberg’s 1913 scientific exploration of North Queensland’s rainforest region. *Memoirs of the Queensland Museum - Culture* 4(1): 1-27.
- Hoffman, R.L. 1980. *Classification of the Diplopoda*. (Muséum d’Histoire Naturelle: Geneva)
- Jeekel, C.A.W. 1968. *On the Classification and Geographical Distribution of the Family Paradoxosomatidae (Diplopoda, Polydesmida)*. (C.A.W. Jeekel: Rotterdam)
1971. Nomenclator generum et familiarum Diplopodorum: a list of the genus and family-group names in the Class Diplopoda from the 10th edition of Linnaeus, 1758, to the end of 1957. *Monografieën van de Nederlandse Entomologische Vereniging* 5: i-xii, 1-412.
1979. Notes on the classification of some little-known Australian paradoxosomatid genera (Diplopoda, Polydesmida). *Journal of Natural History* 13(5): 649-658.
- 1982a. Four new or little-known Australiosomatini from New South Wales (Diplopoda, Polydesmida, Paradoxosomatidae). (Millipedes

- from Australia, 3). *Bijdragen tot de Dierkunde* 52(2): 137-154. (Available online: <http://www.repository.naturalis.nl/document/547736>)
- 1982b. Millipedes from Australia, 2: Antichiropodini from Victoria (Diplopoda, Polydesmida, Paradoxosomatidae). *Bulletin Zoologisch Museum, Universiteit van Amsterdam* 8(24): 201-212. (Available online: <http://www.repository.naturalis.nl/document/549037>)
1984. Millipedes from Australia, 6: Australiosomatini from Victoria (Diplopoda: Polydesmida: Paradoxosomatidae). *Records of the Australian Museum* 36(1): 19-44. (<https://dx.doi.org/10.3853/j.0067-1975.36.1984.323>)
1987. Millipedes from Australia, 11: Australiosomatini from Queensland (Diplopoda, Polydesmida, Paradoxosomatidae). *Beaufortia* 37(2): 11-41. (Available online: <http://www.repository.naturalis.nl/document/548905>)
2000. Millipedes from Australia, 12: Notes on the Paradoxosomatidae of New South Wales, with a key to the genera, and descriptions of a new genus and a new species (Diplopoda, Polydesmida). *Myriapod Memoranda* 2: 31-47.
2006. Millipedes from Australia, 22: A further contribution to New South Wales Australiosomatini (Diplopoda, Polydesmida, Paradoxosomatidae). *Myriapod Memoranda* 9: 79-107.
- Lucas, H. 1840. *Histoire naturelle des Crustacés, des Arachnides et des Myriapodes*. (Duméril: Paris) (Available online: <https://biodiversitylibrary.org/page/30739508>)
- Mesibov, R. 2005. Native species dominate the millipede fauna in a second-rotation *Pinus radiata* plantation in Tasmania, Australia. *Pacific Conservation Biology* 11:17-22.
- 2006-2018. *Millipedes of Australia* [online catalogue], <https://www.polydesmida.info/millipedesofaustralia/>, accessed 1 February 2018.
2008. Diversity of Queensland paradoxosomatid millipedes (Diplopoda: Polydesmida: Paradoxosomatidae). *Australian Entomologist* 35(1): 37-46.
- Musgrave, A. 1926. Tambourine Mountain, Queensland. *Australian Museum Magazine* 2(11): 379-385. (PDF accessed 24 January 2018 at http://web1.australianmuseum.net.au/Uploads/Documents/28558/AMS368_V2-11_lowres.pdf)
1928. In the Macpherson Range. *Australian Museum Magazine* 3(5): 171-180. (PDF accessed 24 January 2018 at http://web1.australianmuseum.net.au/Uploads/Documents/28593/AMS368_V3-5_lowres.pdf)
- Newport, G. 1844. A list of the species of Myriapoda, order Chilognatha, contained in the cabinets of the British Museum, with description of a new genus and thirty-two new species. *Annals and Magazine of Natural History (ser 1)* 13: 263-270. (Available online: <https://biodiversitylibrary.org/page/8550115>)
- Nguyen, A.D. & Sierwald, P. 2013. A worldwide catalog of the family Paradoxosomatidae Daday, 1889 (Diplopoda: Polydesmida). *Check List* 9(6): 1132-1353. (<https://dx.doi.org/10.15560/9.6.1132>)
- Rowe, M. & Sierwald, P. 2006. Morphological and systematic study of the tribe Australiosomatini (Diplopoda: Polydesmida: Paradoxosomatidae: Paradoxosomatidae) and a revision of the genus *Australiosoma* Brölemann. *Invertebrate Systematics* 20(5): 527-556.
- Verhoeff, K.W. 1928. On Diplopoda in the Australian Museum, Sydney. *Records of the Australian Museum* 16(2): 79-115, pls 6-12. (<http://dx.doi.org/10.3853/j.0067-1975.16.1928.782>)
1932. Gliederfüssler: Arthropoda. Klasse Diplopoda. Pp. 1073-2084 in Dr H. G. Bronn's *Klassen und Ordnungen des Tier-Reichs wissenschaftlich dargestellt in Wort und Bild* 5(II)2(7-13). (Akademische Verlagsgesellschaft m.b.H.: Leipzig)
1937. Ueber einige neue Diplopoden aus Australien. *Records of the Australian Museum* 20(2): 133-149. (<http://dx.doi.org/10.3853/j.0067-1975.20.1937.257>)
1941. Zur Kenntnis australischer Strongylosomiden und einiger anderen Diplopoden. *Lunds Universitets Årsskrift (ns 2)* 36(17): 1-25.

Endoparasitic flea larvae of *Uropsylla tasmanica* (Siphonaptera: Pygiopsyllidae) infest spotted-tailed quolls in southern Queensland.

The endemic flea, *Uropsylla tasmanica* Rothschild, 1905 is the sole member of the Australian siphonapteran fauna parasitic at the larval stage and the only member globally with obligatory subcutaneous larvae (Dunnet 1970; Pearse 1981). The species exhibits morphological traits conducive to larval endoparasitism and shows remarkable evolutionary convergence with myiasis-causing Dipteran larvae that exploit a similar habitat (Pearse 1981; Williams 1986; 1991). Larval instars of *U. tasmanica* infest carnivorous dasyurid marsupials, consuming subdermal tissue until pupation (Dunnet 1970; Pearse 1981; Obendorf 1993). This short communication provides the first case reports of *U. tasmanica* in Queensland, extending the known geographic range of this highly specialised and often pathogenic flea.

In late autumn/early winter 2017, two wild, adult, male spotted-tailed quolls *Dasyurus maculatus maculatus* (Kerr, 1792) were collected on separate occasions by wildlife carers in the Southern Downs region of Queensland. The first individual (animal 1) was submitted to veterinarians on 29 May 2017 for euthanasia, but the circumstances and location of collection were not ascertained. Two weeks later on 13 June 2017, a second individual (animal 2) became trapped in a chicken coop on a property in Glen Aplin near Mt Tully and submitted to veterinarians. Both quolls underwent health assessments.

Macroscopically, both individuals were in relatively good nutritional condition but presented with extensive red circular skin lesions on the face, body, legs, tail and scrotum (Figure 1). Lesions contained subcutaneous larvae that were extracted by applying digital pressure to the skin. Alopecia (hair loss) and purulent exudate (evidence of secondary infection) were associated with the lesions. Widespread, concurrent mange infestations were observed in both animals (mite species unidentified). Animal 2 also presented with a ruptured right eyeball, a severely ulcerated left eye and suspected damage to the temporomandibular joint as the range of movement was abnormal and crepitus could be felt with slight palpation. Large numbers of larval instars



FIG. 1. *Uropsylla tasmanica* (Rothschild, 1905) infestation on a spotted-tailed quoll, *Dasyurus maculatus maculatus* (Kerr, 1792).

(>150) were extracted from both quolls by squeezing the parasitized areas. Several dozen larvae removed from the scrotal skin of animal 2 were preserved in 70% ethanol and submitted to the Biosecurity Sciences Laboratory for identification. Upon microscopic examination, second and third instar *U. tasmanica* larvae were identified according to the morphological characters outlined by Pearse (1981). A subsample of voucher specimens was deposited at the Queensland Museum, South Brisbane (reference T239667).

To date, host-parasite associations between *U. tasmanica* and dasyurids from the endemic genera *Dasyurus* (quolls), *Parameles* (bandicoots), *Sarcophilus* (Tasmanian devils) *Thylacinus* (Tasmanian tiger) and the exotic *Felis* (domestic cat) have been documented in Tasmania, Victoria, New South Wales and Western Australia (Dunnet & Mardon 1974; Vilcins *et al.* 2008). To our knowledge, the cases presented here constitute the first reports of *U. tasmanica* in Queensland and extend the known geographic range of this species to the Southern Downs region. These data also represent the most northerly occurrences in Australia to date, several hundred kilometres north of previous reports from the New England Tablelands in NSW (Vilcins *et al.* 2008).

The distribution of *U. tasmanica* in Queensland may correlate with that of its host(s). The spotted-tailed quoll (or tiger quoll) occupies a broad range of habitats in south-east Queensland from the New South Wales border to Gladstone, although populations of this vulnerable subspecies are becoming increasingly fragmented (Meyer-Gleaves 2008; Department of the Environment and Energy 2017). Whether the host range of *U. tasmanica* in Queensland encompasses other dasyurids such as the geographically isolated north-eastern quoll subspecies, *D. maculatus gracilis* Ramsay is not currently known. Additional data would be valuable given the pathogenic potential of the flea and its association with the decline of host populations as documented historically (Pearse 1981; Peacock & Abbot 2014).

The clinical significance of parasitism in these quolls was not fully determined. Larvae from animal 1 were manually removed followed by prolonged anti-helminthic and antibiotic treatment, subsequent rehabilitation and release. Animal 2 was euthanised due to extensive facial trauma and overall poor prognosis unrelated to parasitism. While our gross observations are consistent with previous case reports of *U. tasmanica* infestation (Pearse 1981; Obendorf 1993; Vilcins *et al.* 2008), host immunological and histopathological responses to the flea larvae were not examined (see Vilcins *et al.* 2008; Ladds 2009). Additionally, we were unable to assess the behaviour and health of the animals in the field. In the absence of veterinary intervention, however, parasitism by the larval stages of *U. tasmanica* may have imposed a physical handicap on these quolls. Previous studies have reported partial paralysis, severe disability and death among heavily infested hosts (Pearse 1981; Obendorf 1993). The longer term fitness costs associated with persistent infestation (e.g. mobility, foraging ability, sexual selection) are not currently known. Further studies are required to clarify this point.

Acknowledgements

Our sincere thanks to the Stanthorpe Vetcare Service for their veterinary expertise and laboratory submissions. We also thank Susan Wright and Christine Lambkin at the Queensland Museum for their assistance with registration and deposition of voucher specimens.

Literature cited

Department of the Environment and Energy. 2017. *Dasyurus maculatus maculatus* (SE mainland population) in Species

Uropsylla tasmanica (Siphonaptera: Pygiopsyllidae)

- Profile and Threats Database. Department of the Environment, Canberra. Available from: <http://www.environment.gov.au/sprat>.
- Dunnet, G.M. 1970. Siphonaptera. In, Pp. 647- 655. *The Insects of Australia*. CSIRO (Melbourne University Press: Canberra).
- Dunnet, G.M. & Mardon, D.K. 1974. A monograph of Australian fleas (Siphonaptera). *Australian Journal of Zoology Supplementary Series* 30: 1-273.
- Ladds, P. 2009. *Pathology of Australian Native Wildlife*. (CSIRO Publishing: Victoria).
- Meyer-Gleaves, S. 2010. Ecology and conservation of the spotted-tailed quoll (*Dasyurus maculatus maculatus*) in southern Queensland. PhD thesis. Griffith University: Brisbane.
- Obendorf, D.L. 1993. Diseases of Dasyurid Marsupials. Pp. 39-45. In, Roberts, M., Camio, J., Crawshaw, G. & Hutchins, M. (eds) *The Biology and Management of Australian Carnivorous Marsupials*. (Metropolitan Toronto Zoo and the American Association of Zoological Parks and Aquariums: Toronto, Ontario, Canada).
- Peacock, D. & Abbott, I. 2014. When the 'native cat' would 'plague': historical hyperabundance in the quoll (Marsupialia: Dasyuridae) and an assessment of the role of disease, cats and foxes in its curtailment. *Australian Journal of Zoology* 62(4): 294-344.
- Pearse, A.M. 1981. Aspects of the biology of *Uropsylla tasmanica* (Rothschild) (Siphonaptera). M.Sc. Thesis, University of Tasmania, Hobart.
- Vilcins, I., Old, J.M., Körtner, G. & Deane, E.M. 2008. Ectoparasites and skin lesions in wild-caught spotted-tailed quoll (*Dasyurus maculatus*) (Marsupialia: Dasyuridae). *Comparative Parasitology* 75(2): 271-277.
- Williams, B. 1986. Mandibular glands in the endoparasitic larva of *Uropsylla tasmanica* Rothschild (Siphonaptera: Pygiopsyllidae). *International Journal of Insect Morphology and Embryology* 15(4): 263-268.
- Williams, B. 1991. Adaptations to endoparasitism in the larval integument and respiratory system of the flea *Uropsylla tasmanica* Rothschild (Siphonaptera: Pygiopsyllidae). *Australian Journal of Zoology* 39: 77-90.
- Leanne NELSON¹, Megan BRIDGER² & Shirley TURNER¹. 1. Biosecurity Sciences Laboratory, Health and Food Science Precinct, PO Box 156 Archerfield, BC QLD 4108 Email: leanne.nelson@daf.qld.gov.au. 2. Stanthorpe Vetcare Service, 36 Sugarloaf Rd, Stanthorpe QLD 4380.
- First published online: 30 July 2018. <https://dx.doi.org/10.17082/j.2204-1478.61.2018.2018-07>.
- LSID: [urn:lsid:zoobank.org:pub:0DB0EF5C-4A68-49FF-983B-CAAB49FD7697](http://zoobank.org/pub:0DB0EF5C-4A68-49FF-983B-CAAB49FD7697)

A two-toed population of the critically endangered Retro Slider Skink, *Lerista allanae* (Longman, 1937) (Reptilia: Scincidae)

Amey, A.P.

Couper, P.J.

Worthington Wilmer, J.

Biodiversity and Geosciences Program, Queensland Museum, P.O. Box 3300, South Brisbane Qld 4101, Australia.
Corresponding author email: andrew.amey@qm.qld.gov.au

Ferguson, D.

Borsboom, A.C.

Queensland Herbarium, Mt Coot-tha Rd, Toowong Qld 4066, Australia

Citation: Amey, A.P., Couper, P.J., Worthington Wilmer, J., Ferguson, D. & Borsboom, A.C. 2018. A two-toed population of the critically endangered Retro Slider Skink, *Lerista allanae* (Longman, 1937) (Reptilia: Scincidae). *Memoirs of the Queensland Museum – Nature*. 61: 71–81. Brisbane. ISSN 2204-1478 (Online) ISSN 0079-8835 (Print). Accepted: 24 April 2018. First published online: 3 August 2018

<https://doi.org/10.17082/j.2204-1478.61.2018.2018-04>

LSID urn:lsid:zoobank.org:pub:15F114F4-3A00-471B-8F7D-8F77D629B2D3

ABSTRACT

Surveys to date for the recently re-discovered Retro Slider, *Lerista allanae*, show it to have a narrow, highly restricted distribution. There are currently no populations known to occur in protected areas, with the majority of recent records coming from roadside verges. There is considerable variation in colour pattern and morphology which had not been captured in earlier descriptions based on smaller sample sizes. Colour pattern is commonly grey to tan but some individuals can be very dark to almost black. Additionally, one population possesses two clawed digits on the hind foot, rather than one as seen in all previously examined specimens. While this variation could suggest the presence of cryptic species, a genetic assessment shows it to be intra-specific. The species remains of high conservation significance despite an increase in its Extent of Occurrence.

□ *Conservation, central Queensland, Brigalow Belt, intra-specific variation*

The Retro Slider Skink, *Lerista allanae*, is a species of special interest, which until recently was only known from 13 museum specimens, with most collected in the 1930s. They all came from a small area in the Clermont region of Queensland's Central Brigalow Belt Northern Bioregion. Covacevich *et al.* (1996) reviewed the registration details associated with these specimens and information relating to their collection contained in archival correspondence. These authors also conducted field surveys on Retro Station, the type locality for this species, and surrounding properties. They noted broad

scale changes in land use between 1929 (year of first collection) and 1996 which led them to surmise that *L. allanae* was probably extinct due to the broad scale clearing and degradation of its habitat. In consequence, the species has been listed as Endangered under state and national legislation and Critically Endangered by the IUCN (Australasian Reptile & Amphibian Specialist Group 1996; Australian Government 1999; Queensland Government 1992).

The species was rediscovered in September 2009 when a dead specimen was found in a swimming pool skimmer box on a property

near Clermont. This was sent to the Queensland Museum (specimen QMJ88031) where its identification was confirmed. Follow-up surveys were undertaken to assess the status and extent of the remaining population. The surveys broadened the Area of Occupancy and revealed new information on colour pattern and limb morphology which is reported herein.

METHODS

Surveys conducted since September 2009 have resulted in the capture of a further 20 *L. allanae* specimens. All but one of the specimens were obtained by systematically raking leaf-litter and the underlying friable surface soils beneath trees, shrubs and dead grass mats. A single individual was captured in a pit trap with a short drift fence. Handling of those captured was kept to a minimum. They were weighed using a Pesola spring balance. The snout-vent length and total length was measured using electronic Vernier callipers. Location information was captured using hand-held Garmin 76CSx GPS units. Two specimens were vouchered and lodged at the Queensland Museum (QMJ88428 and QMJ94046). Of those not vouchered, most were photographed and tail tipped (tissue for genetic analyses) then released at their capture site. All survey activities were conducted under DAFF Animal Ethics Committee Approval number SA2013/07/431 and DSITI safety guidelines. Full methods are detailed in Borsboom (2016; 2012), Borsboom *et al.* (2010) and, Borsboom and Ferguson (2015).

Genetics. Couper *et al.* (2016) included two one-toed specimens of *L. allanae* in their recent study of the *Lerista wilkinsi* complex. The current study expanded that dataset by adding eleven new samples, including tissues from both one-toed ($n = 3$, Queensland Museum collection) and two-toed ($n = 8$, this study) populations for a total of thirteen specimens. DNA extraction, amplification (including loci targeted: mitochondrial 12S and 16S ribosomal rRNA (12S, 16S) and NADH dehydrogenase subunit 4 (ND4) including adjacent transfer tRNA fragments tRNA-His, tRNA-Ser and tRNA-Leu (tRNAs) and the nuclear ATP synthetase- β

subunit intron) and sequencing methods, alignment and sequence evolution model choice are as described in Couper *et al.* (2016). All new *L. allanae* sequences were incorporated into the existing alignment generated for Couper *et al.* (2016) and have been deposited in GenBank nucleotide sequence database (see Appendix for details).

Analyses were expanded from Couper *et al.* (2016) with relationships among the two *L. allanae* morphological variants investigated using two different model-based phylogenetic analyses. These were performed via XSEDE (version 3.2.3.) on the CIPRES Science Gateway version 3.3 (Miller *et al.* 2010) using RAxML v8.2.9 (Stamatakis 2014) for maximum likelihood analysis and MrBayes v3.2.6 (Ronquist *et al.* 2012) for Bayesian inference. Both analyses were implemented on the total concatenated dataset incorporating the partitioning strategy found by Skinner (2010) to provide the best fit for the data (7 partitions: 12S, 16S, ND4 first, second and third codon positions, flanking tRNAs and nucATP).

For the maximum likelihood search in RAxML, 1000 bootstrap pseudo-replicates were performed followed by a search for the best performing tree. For the Bayesian inference analyses, we used settings with a Markov chain Monte Carlo of 10 000 000 generations, with the chain sampled every 1000 generations. Burn-in values for each run were set at 2500 000 generations (2500 trees) after empirical values of stabilizing likelihoods and the average standard deviation of the split frequencies reached less than 0.01 indicating that convergence of the MCMC chains had been reached (Posada & Crandall 1998). Maximum clade credibility trees for each run were generated using TreeAnnotator v1.7.5 (as part of the BEAST software package, Drummond *et al.* 2012) with posterior probability limits set for branch support greater than 0.6 (Posada & Crandall 1998).

RESULTS

Distribution. Exact localities will not be disclosed in this paper as the species is highly localised and likely to be sensitive to disturbance (see

Lindenmayer & Scheele 2017 for a discussion of this issue). New records reported in this paper are mapped in relation to historical records in Figure 1.

The type series of *Lerista allanae* was collected in 1936–37 from an unspecified area of Retro Station. At this time, Retro was much larger than its present 2209 ha and parts of ‘old Retro’ now fall within the boundaries of neighbouring properties (Covacevich *et al.* 1996). While no *L. allanae* have been found during recent surveys on the current Retro property, the species is present in areas that were excised from Retro since the type description and one of these may well be the site from where the type series was collected. Surveys since September 2009 have found *L. allanae* at four new sites, two with single records only. Two estimates of a species’ range size used and defined by the IUCN are Extent of Occurrence (EOO) and Area of Occupancy (AOO) (IUCN 2012). Using the data we have collected for *L. allanae*, these parameters are 100 km² for EOO and <10 km² for AOO. An AOO of 40.7 ha was derived from 100 m buffers around vouchered records, the AOO adjusted for overlapping buffers. The recent records are associated with clumps of trees and shrubs surrounded by grassland and most of these are along road easements. Consequently, most of the survey effort has focussed on roadside vegetation with the known EOO being largely linear, extending 40 km in a north/south direction between Clermont and Emerald. Although the EOO may increase with further survey effort, it is likely to remain narrow and to have been greatly reduced by extensive land clearing practices from 1940 onwards (Covacevich *et al.* 1996). Preliminary surveys in an east-west direction have, to date, failed to extend the distribution. A specimen in the South Australian Museum, collected prior to November 1948, came from Logan Downs, around 40 km to the north, suggesting that, historically, the distribution was more extensive. It should be noted however that, like Retro Station, Logan Downs was much more extensive in 1948 than its present area so the accuracy of this record is low.

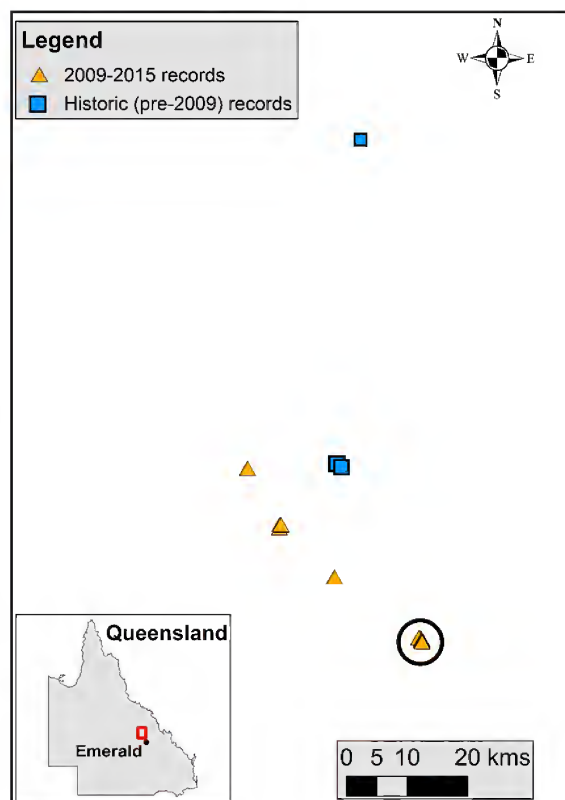


FIG. 1. Map showing new records of *Lerista allanae* obtained in this study in relation to historical records. Two-toed *L. allanae* records are circled.

Toe morphology. The presence of a monodactyl hind limb with a single clawed digit is regarded as diagnostic for *L. allanae* (Fig. 2A; Cogger 2014; Longman 1937). This condition, reported from the small series of specimens then available, is not constant with some individuals encountered during the present study bearing didactyl hind limbs (11 of 36 records; Fig. 2B). This condition may be confined to the most southern population where it was observed in all individuals captured (11/11). Twelve of the 13 specimens held in museum collections come from north of Capella and these all have monodactyl hind limbs. Where a second digit is present, it is small, around 40% the length of the longer digit (in QMJ94046, shown in Fig 2B, a vouchered specimen from the southern population, the second digit is only 0.7 mm

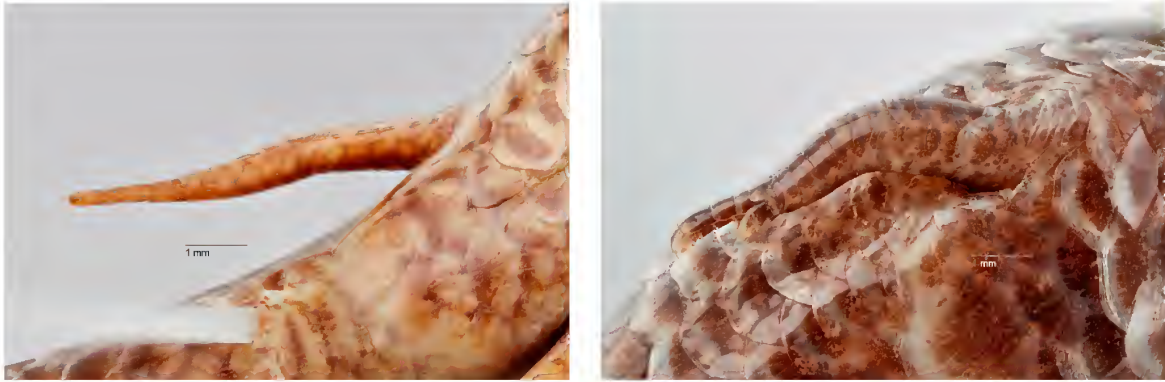


FIG. 2. Toe arrangement of *Lerista allanae*; **A**, the more common single digit (QMJ6430); **B**, two toes (QMJ94046). Photos by G. Thompson.

long and bears three subdigital lamellae). The claw is poorly developed, its tip only just extending beyond the surrounding scales. Consequently, the second digit could be easily overlooked and this character may conceivably have been missed in some of the released specimens from the more northern populations (seven individuals).

Colour Pattern. In life, *L. allanae* is usually coppery-brown above with the dorsal colouration two to three scale rows either side of the vertebral line (this contrasts with Longman's 1937 description of preserved material 'Ridgeway's drab gray'). This colour is particularly rich in juveniles (Fig. 3A) but tends to fade towards tan in larger individuals (Fig. 3B).

Adults. The dorsal pattern generally consists of a series of four or more almost continuous, dark longitudinal lines extending from the nuchals

to the base of the tail, with individual scales marked with a dark posterior edge or streak. The flanks are usually lighter, off-white to cream with the posterior half of each scale dark brown to black, producing a heavily spotted or speckled effect which usually extends to the ventral surface (referred to as 'prettily marked with dark spots' in type description, Longman, 1937). In some specimens the ventral scales have finer dark edges giving a more reticulated appearance. Head shields are coppery to tan with dark edging and scattered blotches. Upper labials are strongly pigmented. Tip of snout (rostral, mental, nasals, first supralabial and first infralabial) sometimes with a waxy opaque appearance (this may relate to a stage in skin sloughing and is characteristic of *Lerista*, Greer 1989).

Juveniles. The pattern is generally more speckled than in adults with the dark dorsal lines less well defined. Most of the juveniles from the south Capella site were coppery brown above with dark edges to the scales giving a reticulated appearance that breaks into dark speckling with increasing size. Ventral surface as for adults although in some individuals the dark reticulations are more extensive giving the appearance of a darker ventral surface.

Melanistic pattern. Some specimens are so strongly pigmented their general appearance is dark brown to black. In QMJ88428 (a juvenile) there is little demarcation between the dorsal,

TABLE 1: Average sequence divergence for *Lerista allanae*.

Locus	Within One-toed	Within Two-toed	Between One-toed and Two-toed	Ave among all <i>Lerista</i> species
12S	0.6%	0.4%	0.4%	8.61%
16S	0.9%	0.3%	0.3%	6.52%
ND4	1.0%	0.4%	0.2%	13.45%
tRNAs	2.0%	0.0%	0.2%	12.37%
nucATP	0.00%	0.00%	0.00%	3.82%



FIG 3. Colour variability in *Lerista allanae*; A, coppery brown pattern most often seen in juveniles (tissue sample QMA13152); B, most frequently seen tan colour (tissue sample QMA13156); C, the dark colour pattern observed in some southern individuals (QMJ94046). Photos by D. Ferguson.

lateral and ventral colours, the flanks are strongly speckled and the ventral surface is tinged with brown. Specimen QMJ94046 (adult, Fig. 3C) is extremely dark, both above and below, although, with closer scrutiny, dark scale edges, spots and speckles are still discernible.

Genetic assessment. Both maximum likelihood and Bayesian inference phylogenetic analyses returned near identical topologies and clearly support the southern two-toed and northern one-toed populations as a single, monophyletic species with maximum bootstrap (100) and posterior probability (1.00) support respectively (Fig. 4). Furthermore, genetic differences among the two morphotypes are minimal, with average sequence divergence estimates ranging between 0.0–0.4% across all loci (Table 1).

DISCUSSION

Lerista allanae was thought to be extinct but is now known to persist in a small area of central Queensland. The few specimens available prior to its rediscovery in 2009 did not allow a full description of the morphological variability within this species. An ability to confidently identify a species in the field is critical to its management. With more specimens and genetic information, we have a better understanding of intraspecific variability. Morphological variability is proving to be a common feature of *Lerista*. Several Western Australian species have a variable number of digits (for example, the three-toed *L. kalumburu* has a geographically discrete population of two-toed individuals within it; Amey & Worthington Wilmer 2014). However, this phenomenon seems to be less common in eastern Australia, where the hind limb arrangement has been seen as a diagnostic character for separating species, for example, *L. emmotti* from *L. punctatovittata* and *L. allanae* from *L. colliveri* (Couper & Ingram 1992; Ingram *et al.* 1993). While genetic analysis shows these to be valid species (Skinner 2010), it is plain that relying on morphological evidence alone to diagnose species of *Lerista* can, at times, be unsatisfactory.

While some variability of colour pattern is common within species of *Lerista*, it normally consists of variation in the intensity of stripes, from indistinct rows of spots to clearly defined stripes. The extremes observed within the small population of *L. allanae* have not been documented in any other species. The significance of this variability is unclear.

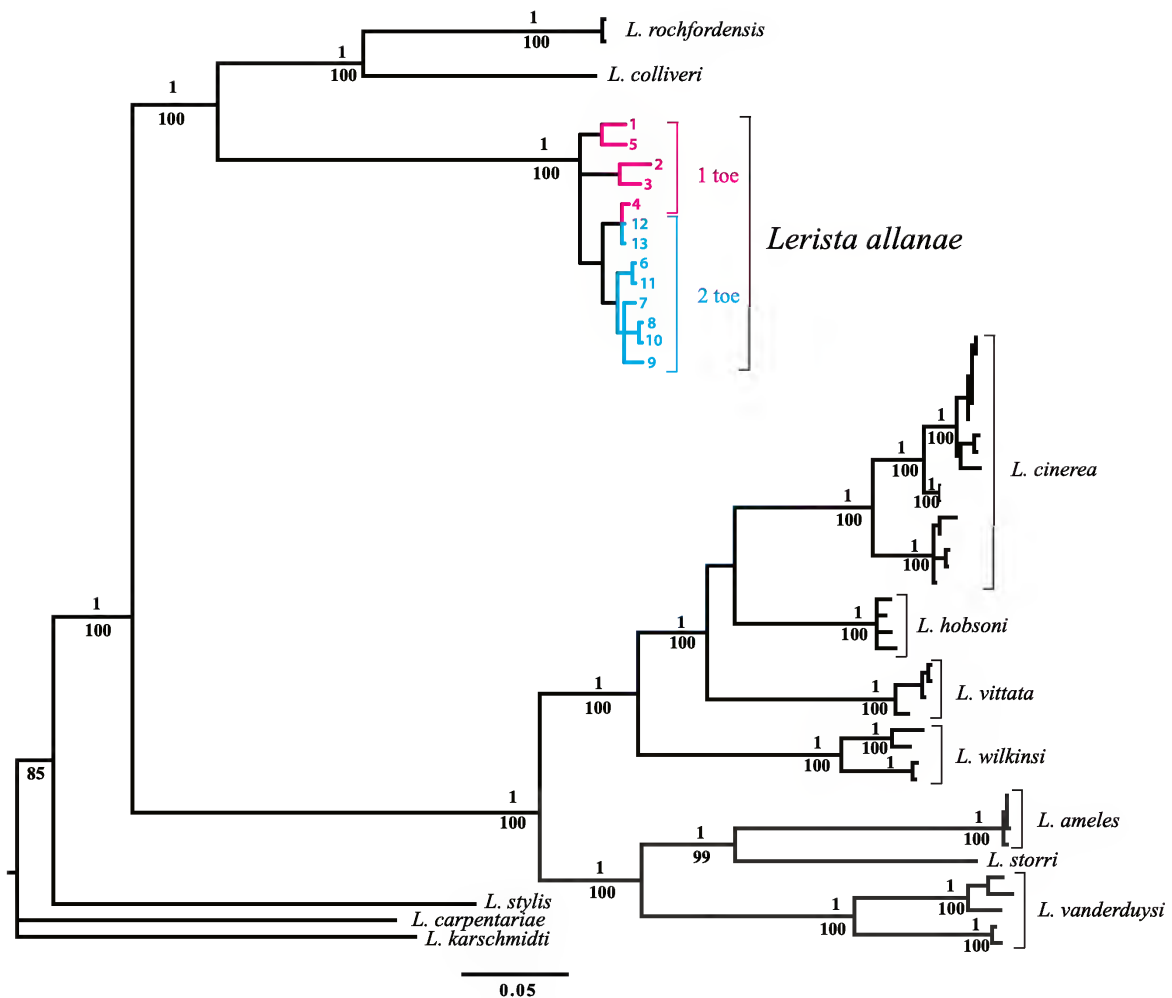


FIG 4. Maximum-likelihood tree based on the full concatenated dataset. Clade support is indicated by bootstrap values ≥ 70 below the branch and posterior probabilities ≥ 0.95 representing a topologically identical maximum clade credibility Bayesian tree are above the branch. Scale represents average number of substitutions per site.

The surveys described herein have increased the known EOO for *L. allanae* but the species remains highly localised in a modified landscape with additional disturbance potentially elevating its risk of extinction. The AOO is entirely outside of protected areas and is confined to a narrow strip adjacent to areas of intense agricultural activity on one side and a main road on the other. Work on other *Lerista* species in north Queensland shows they have naturally

fragmented distributions, being isolated in small patches of suitable habitat, i.e., friable soil that they can 'swim' through (Couper *et al.* 2016). This makes them vulnerable to disturbance as a reasonably small-scale development has the potential to eliminate entire populations and their limited dispersal ability makes recolonization of disturbed areas unlikely. Almost the entire known range of *L. allanae* is now confined to roadside easements, areas that are potentially

impacted by road and rail works, invasive weeds, weed control, grazing, fire and the activities of reptile enthusiasts keen to tick another species off their 'twitcher' lists.

Lerista allanae is a cryptic, fossorial species that requires intensive survey effort to uncover. This is why, despite the survey effort that has occurred since its rediscovery, the full distribution of *L. allanae* remains largely unknown. The record from Logan Downs (registered in 1948) is furthest from the new records, suggesting a wider former distribution but the historical distribution must remain speculative.

The most effective survey technique for *L. allanae* to date, raking through leaf litter and the subsoil environment, involves disruption to a sensitive, very limited microhabitat. Because of this potential damage, future searches for *L. allanae* should only be undertaken by approved personnel in attempts to extend its distribution or to confirm its continued existence at known localities following habitat disturbance or other causes for concern. While surveys without clear, defensible conservation goals must be avoided, surveys of suitable habitat on surrounding properties are recommended in order to locate additional populations. *Lerista allanae* remains one of Australia's most critically endangered reptiles.

ACKNOWLEDGEMENTS

We thank the property owners of the Clermont area for allowing free access to survey and Geoff Thompson, QM, for photography.

LITERATURE CITED

- Amey, A.P. & Worthington Wilmer, J. 2014. Morphological diversity and genetic structure within *Lerista kalumburu* Storr, 1976 (Squamata: Scincomorpha: Sphenomorphidae) – taxonomic implications. *Zootaxa*, **3821**: 239–252. <http://dx.doi.org/10.11646/zootaxa.3821.2.4>
- Australasian Reptile & Amphibian Specialist Group 1996. *Lerista allanae*. *The IUCN Red List of Threatened Species* 1996: e.T11804A3309620. <http://dx.doi.org/10.2305/IUCN.UK.1996.RLTS.T11804A3309620.en>
- Australian Government 1999. Environment Protection and Biodiversity Conservation Act C2016C00667, Canberra, ACT. Available from: <https://www.legislation.gov.au/Details/C2016C00667> (Accessed 28 June, 2016).
- Borsboom, A. 2016. Surveys for *Lerista allanae* and *Egernia rugosa* in Peak Range National Park in 2015. Department of Science, Information Technology and Innovation, Queensland Government, Brisbane.
- Borsboom, A.C. 2012. Roadside survey and management recommendations for the endangered skink *Lerista allanae*. Queensland Herbarium, Queensland Department of Science, Information Technology, Innovation and the Arts: Brisbane.
- Borsboom, A.C., Couper, P.J., Amey, A., Hobson, R. & Wilson, S.K. 2010. Rediscovery of the endangered Retro Slider (*Lerista allanae*) in the Clermont region of central Queensland. Dept of Environment and Resource Management, Brisbane, 29 pp.
- Borsboom, A.C. & Ferguson, D.J. 2015. Surveys for the endangered skink *Lerista allanae* in February 2015. Department of Science, Information Technology and Innovation, Queensland Government, Brisbane, 17 pp.
- Cogger, H.G. 2014. *Reptiles & Amphibians of Australia* (7th ed.). (CSIRO Publishing: Collingwood).
- Couper, P.J., Amey, A.P. & Worthington Wilmer, J. 2016. Cryptic diversity within the narrowly endemic *Lerista wilkinsi* group of north Queensland – two new species (Reptilia: Scincidae). *Zootaxa*, **4162**: 61–91. <http://doi.org/10.11646/zootaxa.4162.1.3>
- Couper, P.J. & Ingram, G.J. 1992. A new species of skink of *Lerista* from Queensland and a re-appraisal of *L. allanae* (Longman). *Memoirs of the Queensland Museum*, **32**: 55–59.
- Covacevich, J.A., Couper, P.J. & McDonald, K.R. 1996. *Lerista allanae* (Scincidae: Lygosominae): 60 years from exhibition to extinction? *Memoirs of the Queensland Museum*, **39**: 247–256.
- Drummond, A.J., Suchard, M.A., Xie, D. & Rambaut, A. 2012. Bayesian phylogenetics with BEAUti and the BEAST 1.7. *Molecular Biology and Evolution*, **29**: 1969–1973.
- Greer, A.E. 1989. *The Biology and Evolution of Australian Lizards*. (Surrey Beatty & Sons: Sydney).
- Ingram, G.J., Couper, P.J. & Donnellan, S.C. 1993. A new two-toed skink from eastern Australia. *Memoirs of the Queensland Museum*, **33**: 341–347.
- IUCN 2012. *IUCN Red List Categories and Criteria: Version 3.1* (2nd ed.). (IUCN: Gland Switzerland and Cambridge, UK).
- Lindenmayer, D.B. & Scheele, B. 2017. Do not publish. *Science*, **356**: 800–801.
- Longman, H.A. 1937. Herpetological notes. *Memoirs of the Queensland Museum*, **11**: 165–168.

- Miller, M.A., Pfeiffer, W. & Schwartz, T. 2010. Creating the CIPRES Science Gateway for inference of large phylogenetic trees. Pp. 1–8. *In*, *Proceedings of the Gateway Computing Environments Workshop (GCE)*: New Orleans).
- Posada, D. & Crandall, K.A. 1998. Modeltest: Testing the model of DNA substitution. *Bioinformatics*, **14**: 817–818. <http://dx.doi.org/10.1093/bioinformatics/14.9.817>
- Queensland Government 1992. Nature Conservation Act, Brisbane, Queensland. Available from: https://www.legislation.qld.gov.au/acts_sl/Acts_SL_N.htm (Accessed 28 June, 2016).
- Ronquist, F., Teslenko, M., Van Der Mark, P., Ayres, D.L., Darling, A., Hohna, S., et al. 2012. MRBAYES 3.2: Efficient Bayesian phylogenetic inference and model selection across a large model space. *Systematic Biology*, **61**: 539–542. <http://dx.doi.org/10.1093/sysbio/sys029>
- Skinner, A. 2010. Rate heterogeneity, ancestral character state reconstruction and the evolution of limb morphology in *Lerista* (Scincidae, Squamata). *Systematic Biology*, **59**: 723–740. <http://dx.doi.org/10.1093/sysbio/syq055>
- Stamatakis, A. 2014. RAXML Version 8: A tool for phylogenetic analysis and post-analysis of large phylogenies. *Bioinformatics*, **30**: 1312–1313. <https://doi.org/10.1093/bioinformatics/btu033>

APPENDIX

Tissue registration and GenBank sequence numbers for material examined in this study.

Species	Tissue Number	12S rRNA	16S rRNA	ND4+tRNAs	ATP
<i>Lerista allanae</i> - Capella 1	QM A005540	KU309145	KU309187	KU309272	KU309229
<i>Lerista allanae</i> - Capella 2	QM A006515	KU309146	KU309188	KU309273	KU309230
<i>Lerista allanae</i> - Capella 3	QM A006531	MF959776	MF959787	MF959798	MF959808
<i>Lerista allanae</i> - Capella 4	QM A009274	MF959777	MF959788	N/A	MF959809
<i>Lerista allanae</i> - Capella 5	QM A009277	MF959778	MF959789	MF959799	MF959810
<i>Lerista allanae</i> - Capella 6	QM A013150	MF959779	MF959790	MF959800	MF959811
<i>Lerista allanae</i> - Capella 7	QM A013151	MF959780	MF959791	MF959801	MF959812
<i>Lerista allanae</i> - Capella 8	QM A013153	MF959781	MF959792	MF959802	MF959813
<i>Lerista allanae</i> - Capella 9	QM A013154	MF959782	MF959793	MF959803	MF959814
<i>Lerista allanae</i> - Capella 10	QM A013155	MF959783	MF959794	MF959804	MF959815
<i>Lerista allanae</i> - Capella 11	QM A013156	MF959784	MF959795	MF959805	MF959816
<i>Lerista allanae</i> - Capella 12	QM A013157	MF959785	MF959796	MF959806	MF959817
<i>Lerista allanae</i> - Capella 13	QM A013158	MF959786	MF959797	MF959807	MF959818
<i>Lerista ameles</i> - Mt Surprise 1	ABTC 77124	KU309147	KU309189	KU309274	KU309231
<i>Lerista ameles</i> - Mt Surprise 2	ABTC 77125	KU309148	KU309190	KU309275	KU309232
<i>Lerista ameles</i> - Mt Surprise 3	ABTC 77144	KU309149	KU309191	KU309276	KU309233
<i>Lerista ameles</i> - Mt Surprise 4	ABTC 77171	KU309150	KU309192	KU309277	KU309234
<i>Lerista cinerea</i> - Warrawee Station 1	QM A013421	KU309151	KU309193	KU309278	KU309235
<i>Lerista cinerea</i> - Warrawee Station 2	QM A013422	KU309152	KU309194	KU309279	KU309236

Appendix continued ...

Species	Tissue Number	12S rRNA	16S rRNA	ND4+tRNAs	ATP
<i>Lerista cinerea</i> - Warrawee Station 3	QM A013423	KU309153	KU309195	KU309280	KU309237
<i>Lerista cinerea</i> - Warrawee Station 4	QM A013424	KU309154	KU309196	KU309281	KU309238
<i>Lerista cinerea</i> - Warrawee Station 5	QM A013425	KU309155	KU309197	KU309282	KU309239
<i>Lerista cinerea</i> - Warrawee Station 6	QM A013426	KU309156	KU309198	KU309283	KU309240
<i>Lerista cinerea</i> - Bletchington Park	QM A006562	KU309157	KU309199	KU309284	KU309241
<i>Lerista cinerea</i> - Gregory Development Rd	QM A013451	KU309158	KU309200	KU309285	KU309242
<i>Lerista cinerea</i> - Rishton Scrub 1	QM A013427	KU309159	KU309201	KU309286	KU309243
<i>Lerista cinerea</i> - Rishton Scrub 2	QM A013428	KU309160	KU309202	KU309287	KU309244
<i>Lerista cinerea</i> - Rishton Scrub 3	QM A013429	KU309161	KU309203	KU309288	KU309245
<i>Lerista cinerea</i> - Sellheim Scrub 1	QM A013430	KU309162	KU309204	KU309289	KU309246
<i>Lerista cinerea</i> - Sellheim Scrub 2	QM A013431	KU309163	KU309205	KU309290	KU309247
<i>Lerista cinerea</i> - Sellheim Scrub 3	QM A013432	KU309164	KU309206	KU309291	KU309248
<i>Lerista cinerea</i> - Sellheim Scrub 4	QM A013433	KU309165	KU309207	KU309292	KU309249
<i>Lerista cinerea</i> - Sellheim Scrub 5	QM A013434	KU309166	KU309208	KU309293	KU309250
<i>Lerista colliveri</i>	QM A003450	KU309167	KU309209	KU309294	KU309251
<i>Lerista hobsoni</i> - Lolworth Homestead 1	ABTC 72912	KU309168	KU309210	N/A	KU309252
<i>Lerista hobsoni</i> - Lolworth Homestead 2	ABTC 72913	KU309169	KU309211	KU309295	KU309253
<i>Lerista hobsoni</i> - Lolworth Homestead 3	ABTC 72914	KU309170	KU309212	KU309296	KU309254
<i>Lerista hobsoni</i> - Pentland	QM A013450	KU309171	KU309213	KU309297	KU309255
<i>Lerista rochfordensis</i> - Barrabas Scrub 1	QM A013440	MF589181	MF589191	MF589212	MF589202
<i>Lerista rochfordensis</i> - Barrabas Scrub 2	QM A013441	MF589182	MF589192	MF589213	MF589203
<i>Lerista rochfordensis</i> - Barrabas Scrub 3	QM A013442	MF589183	MF589193	MF589214	MF589204
<i>Lerista rochfordensis</i> - Barrabas Scrub 4	QM A013443	N/A	MF589194	MF589215	MF589205

Appendix continued ...

Species	Tissue Number	12S rRNA	16S rRNA	ND4+tRNAs	ATP
<i>Lerista rochfordensis</i> - Barrabas Scrub 5	QM A013444	MF589184	MF589195	MF589216	MF589206
<i>Lerista rochfordensis</i> - Barrabas Scrub 6	QM A013445	MF589185	MF589196	MF589217	N/A
<i>Lerista rochfordensis</i> - Barrabas Scrub 7	QM A013446	MF589186	MF589197	MF589218	MF589207
<i>Lerista rochfordensis</i> - Barrabas Scrub 8	QM A013447	MF589187	MF589198	MF589219	MF589208
<i>Lerista rochfordensis</i> - Rochford Scrub 1	QM A013435	KU309172	KU309214	KU309298	KU309256
<i>Lerista rochfordensis</i> - Rochford Scrub 2	QM A013436	KU309173	KU309215	KU309299	KU309257
<i>Lerista rochfordensis</i> - Rochford Scrub 3	QM A013437	MF589188	MF589199	MF589220	MF589209
<i>Lerista rochfordensis</i> - Rochford Scrub 4	QM A013438	MF589189	MF589200	MF589221	MF589210
<i>Lerista rochfordensis</i> - Rochford Scrub 5	QM A013439	MF589190	MF589201	MF589222	MF589211
<i>Lerista storri</i> - Almaden	QM A005045	KU309174	KU309216	KU309300	KU309258
<i>Lerista vanderduysi</i> - Blackbraes 1	QM A000418	KU309175	KU309217	KU309301	KU309259
<i>Lerista vanderduysi</i> - Blackbraes 2	QM A001142	KU309176	KU309218	KU309302	KU309260
<i>Lerista vanderduysi</i> - Blackbraes 3	QM A002098	KU309177	N/A	N/A	KU309261
<i>Lerista vanderduysi</i> - Gilbert Station 1	QM A008448	KU309178	KU309219	N/A	KU309262
<i>Lerista vanderduysi</i> - Gilbert Station 2	QM A008462	N/A	KU309220	N/A	KU309263
<i>Lerista vittata</i> - Mt Cooper Station 1	QM A013417	KU309179	KU309221	KU309303	KU309264
<i>Lerista vittata</i> - Mt Cooper Station 2	QM A013418	KU309180	KU309222	KU309304	KU309265
<i>Lerista vittata</i> - Mt Cooper Station 3	QM A013419	KU309181	KU309223	KU309305	KU309266
<i>Lerista vittata</i> - Mt Cooper Station 4	QM A013420	KU309182	KU309224	KU309306	KU309267
<i>Lerista wilkinsi</i> - Torrens Creek 1	ABTC 76998	KU309183	KU309225	KU309307	KU309268
<i>Lerista wilkinsi</i> - Torrens Creek 2	ABTC 121865	KU309184	KU309226	KU309308	KU309269
<i>Lerista wilkinsi</i> - Torrens Creek 3	QM A013448	KU309185	KU309227	KU309309	KU309270
<i>Lerista wilkinsi</i> - Torrens Creek 4	QM A013449	KU309186	KU309228	KU309310	KU309271

Appendix continued ...

Species	Tissue Number	12S rRNA	16S rRNA	ND4+tRNAs	ATP
Outgroups					
<i>Lerista carpentariae</i>	N/A	EF672763	EF672834	EF672975	EF672905
<i>Lerista karlschmidti</i>	N/A	EF672787	EF672858	EF672999	EF672929
<i>Lerista stylis</i>	N/A	EF672811	EF672882	EF373023	EF672952
Abbreviations ABTC = Australian Biological Tissue Collection QM = Queensland Museum					

A revision of Charopidae with a finely cancellate protoconch sculpture from mid-eastern Queensland (Eupulmonata: Charopidae)

Lorelle HOLCROFT

School of Environment and Science, Australian Rivers Institute, Griffith University, Nathan campus, 170 Kessels Road, Nathan Qld 4111; Queensland Museum, PO Box 3300, South Brisbane Qld 4101. Email: lorelle.holcroft@griffithuni.edu.au; lorelle.holcroft@bigpond.com

Citation: Holcroft, L. 2018. A revision of Charopidae with a finely cancellate protoconch sculpture from mid-eastern Queensland (Eupulmonata: Charopidae). *Memoirs of the Queensland Museum - Nature* 61: 83–107. Brisbane. ISSN 2204-1478 (Online) ISSN 0079-8835 (Print). Accepted: 12 June 2018. First published online: 27 September 2018.

<https://doi.org/10.17082/j.2204-1478.61.2018.2018-09>

LSID urn:lsid:zoobank.org:pub:9BDA53D5-C25F-4872-ABF0-1996CC7067BC

ABSTRACT

This study reviews the charopid land snails of mid-eastern Queensland possessing finely cancellate sculpture on the protoconch. Microscopic features of shell sculpture and qualitative and quantitative measurements of conchological features are utilised to delimit species due to lack of animal material suitable for DNA analysis. This study confirms the generic status of *Pereduropa* Stanislav, 2010 and *Isolderopa* Stanislav, 2010 and expands the brief descriptions of the species previously described in these genera. One new species of *Pereduropa*, *P. burwelli* sp. nov. and three new species of *Isolderopa* viz. *I. teemburra* sp. nov., *I. diamante* sp. nov. and *I. whitsunday* sp. nov. are described. A new genus, *Tristanoropa* gen. nov., is diagnosed for two new species *T. hughesae* sp. nov. and *T. conwayensis* sp. nov. □ *Mollusca, Eupulmonata, Charopidae, protoconch sculpture, finely cancellate, new genera, new species.*

Charopids are tiny land snails and their size (shell diameter 1–7 mm) and often cryptic habitat make them difficult to find alive and as a result they are generally collected as dead shells from leaf litter sorting. Consequently, identification of charopid species and their assignment to genera has required a strong emphasis on shell morphology and in particular, protoconch sculptural patterns (Hyman & Stanislav 2005; Shea *et al.* 2012; Stanislav 2016; Holcroft 2018a). This study reviews the charopid land snails of mid-eastern Queensland possessing finely cancellate protoconchs and is part of a larger revision of the Charopidae (Pinwheel Snails) of mid-eastern Queensland (Holcroft 2018b).

The eastern Australian charopids have been shown to possess eleven major protoconch sculptural patterns formed by a combination of

spiral cords and radial ribs (Holcroft 2018a). The finely cancellate sculptural pattern is one where narrow, raised spiral cords or threads and narrow, raised radial ribs of similar dimensions combine to give a net-like appearance when viewed under scanning electron microscopy (SEM). Personal observation reveals this pattern is more prevalent in the smallest of the Australian charopids (those with a shell diameter less than 2.6 mm) currently assigned to *Rotacharopa* Stanislav, 1990, *Pereduropa* Stanislav, 2010, *Isolderopa* Stanislav, 2010, *Excaliburopa* Stanislav, 2010, *Shearopa* Stanislav, 2010 and *Ygernaropa* Stanislav, 2010. Within this baseline pattern, there are a number of variations such as ‘scalloped’ and ‘webbed’ which further define individual genera.

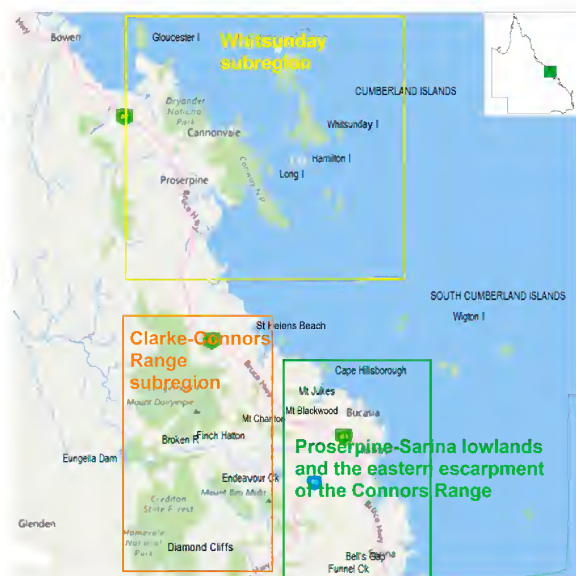


FIG. 1. Mid-eastern Queensland showing major collection areas.

In this study, six described and six newly described species of charopid from mid-eastern Queensland (Fig. 1) are shown to have a finely cancellate protoconch sculpture. All are tiny and less than 2.6 mm in shell diameter. Stanisic *et al.* (2010) introduced two genera with nautiloid coiling patterns to incorporate the six described species mentioned above. *Pereduropa* comprised minute charopids with a brown shell and a slightly elevated spire. In contrast, *Isolderopa* included minute charopids with a brown, biconcave shell, a depressed to very depressed spire and in two species, apertural barriers. Apertural barriers appear shortly after hatching and are added to anteriorly and reabsorbed posteriorly during subsequent growth (Solem 1983: 15) and at times disappear altogether in adulthood (Stanisic pers. comm.). This character is not a feature of any *Pereduropa* species.

Four new species belonging to these genera, *P. burwelli* sp. nov., *I. teemburra* sp. nov., *I. diamante* sp. nov. and *I. whitsunday* sp. nov. are described. *Tristanoropa* gen. nov., is diagnosed for two new species with finely cancellate protoconchs and a multi-whorled coiling pattern, viz. *T. hughesae* sp. nov. and *T. conwayensis* sp. nov.

Abbreviations. General: SEM, scanning electron microscopy; SC, spirit collection; RC, dry collection. Institutions: AM, Australian Museum, Sydney; QM, Queensland Museum, Brisbane. Habitat Data: alt, altitude; Ck, Creek; cnvf, complex notophyll vine forest; Hts, Heights; I., Island; MEQ, Mid-eastern Queensland; Mt, Mountain; Mts, Mountains; NENSW, North-eastern New South Wales; NEQ, North-eastern Queensland; NP, National Park; NSW, New South Wales; nvf, notophyll vine forest; R, River; Ra, Range; SEQ, South-eastern Queensland; sevt, semi-evergreen vine thicket; SF, State Forest; WT, Wet Tropics. Shell features: AH, aperture height; AW, aperture width; D, shell diameter; D/U, ratio of shell diameter to umbilical width; H, shell height; H/D, ratio of shell height to shell diameter; PD, protoconch diameter; PL, protoconch length; T1, 1st whorl of the teleoconch; U, umbilical width; WWB, number of ribs on the 3rd quarter of the body whorl.

MATERIALS AND METHODS

The study was chiefly based on material held in the Queensland (Brisbane) and Australian (Sydney) Museums. Individual specimens are identified by their registration number and respective institutional prefix (QMMO, Queensland Museum; AMSC, Australian Museum). Undescribed species in the collections of these museums are identified by a family descriptor and an alpha-numeric codon e.g. Charopid WT 41.

Adult shells were measured using a Camera Lucida mounted on a WILD M5 stereo microscope. Measurements were converted from ocular micrometre units to mm using a conversion factor at a set magnification. Characters investigated included shell shape, size (height and diameter), whorl count, coiling pattern, protoconch diameter, protoconch whorl length, rib count and umbilical width. Standard definitions (Solem 1983) for most conchological characters were used and whorl counts were made to the nearest 1/8 whorl.

High resolution images of shells (260-600MB) were obtained using a Visionary Digital BK-Plus

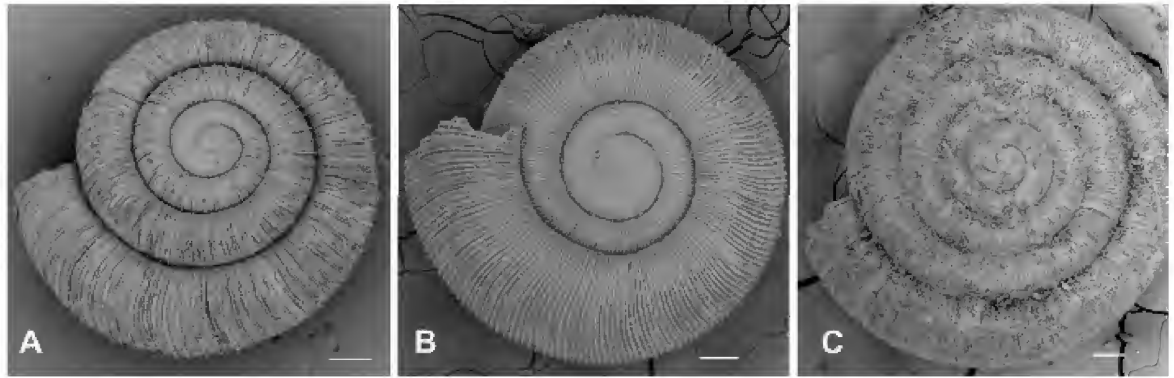


FIG. 2. Coiling patterns of the finely cancellate genera of MEQ. A, Nautiloid shell with flat spire of *Pereduropa* (*P. cursacosta* sp. nov., QMMO11901, Cape Hillsborough); B, Nautiloid shell with depressed spire of *Isolderopa* (*I. whitsunday* sp. nov., QMMO11902, Cape Hillsborough); C, Multi-whorled shell of *Tristanoropa* gen. nov. (*T. hughesae* sp. nov., QMMO50887, Eungella NP). Scale bars = 100 μ m.

lab system camera set-up in the Queensland Museum's Digital Imaging Unit.

The shell sculpture of specimens was investigated and photographed using a TM-1000 Tabletop Scanning Electron Microscope located at the Queensland Museum. Shells were cleaned in an ultrasonic cleaner but not by chemical means in order to prevent the removal of the periostracum which protects many of the shell's sculptural elements. Specimens were mounted on sticky tabs, gold sputter coated and imaged under high vacuum. Sculptural patterns of both the protoconch and teleoconch were extensively examined.

RESULTS

Shell morphology

Shell coiling patterns. Protoconch sculpture has been increasingly used to define charopid genera (Solem 1983; Stanisic 1990, 1998; Hyman & Stanisic 2005; Shea *et al.* 2012). However other morphological features of shells can be used in conjunction with this character (Solem 1983). In this study, where all species have a finely cancellate protoconch, other shell characters have been used. When the protoconch pattern is similar across genera, shell coiling pattern and spire protrusion play a significant role in the delimitation of genera. Both nautiloid

and multi-whorled forms are evident within MEQ charopids. *Pereduropa* has an evenly coiled nautiloid form with a flat to raised spire (Fig. 2A), *Isolderopa* has a more tightly coiled, laterally compressed, nautiloid form with a depressed spire (Fig. 2B) and *Tristanoropa* gen. nov. has a tightly multi-whorled shell where the body whorl does not flare as in the previous two genera (Fig. 2C).

Shell measurements. Means of the shell measurements of all species examined in this study are shown in Table 1 and measurements of all individual specimens are tabulated in the Appendix. Within *Pereduropa* all species were differentiated by the protoconch diameter and the number of ribs on the first whorl of the teleoconch. *Pereduropa burwelli* sp. nov. was distinguished from other *Pereduropa* spp. by a large D/U ratio, a larger protoconch diameter and greater number of ribs on the first whorl of the teleoconch than the previously described species.

Isolderopa species shared a similar protoconch diameter with the exception of one species, *I. minuta* Stanisic, 2010, which had an unusually tiny protoconch diameter of 250 μ m, a much smaller shell diameter and much finer ribbing on the teleoconch. The aperture height and width of *I. iangallowayi* Stanisic, 2010, in addition to its tighter coiling, distinguishes

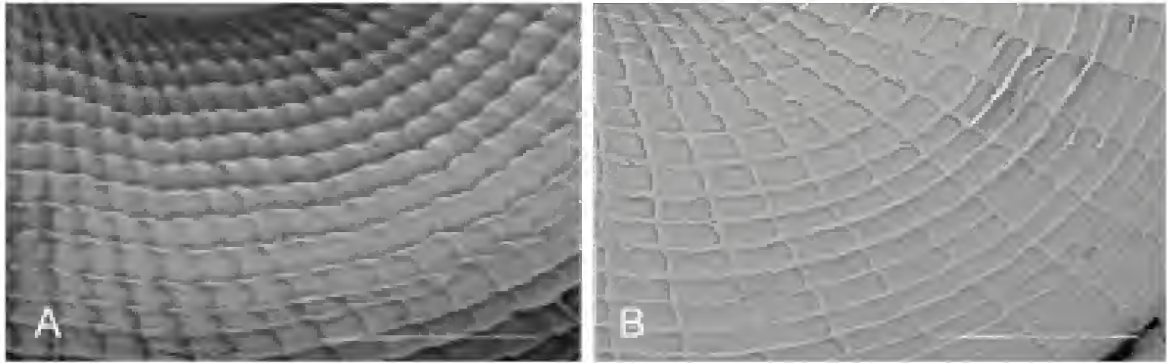


FIG. 3. Finely cancellate protoconch sculptural variations. A, Scalloped variant of *Isolderopa iangallowayi*, QMMO85080, Pelion SF, MEQ; B, Webbed variant of Charopid SQ78, QMMO13463, Biloela, SEQ. Scale bars = 50 μ m.

this species from its congeners. D/U ratios differentiate *I. deliqua* Stanisic, 2010, *I. teemburra* sp. nov. and *I. whitsunday* sp. nov. from each other. *Isolderopa diamante* sp. nov. though larger in shell diameter than *I. minuta*, was much smaller in this measurement and D/U ratio than its congeners. The form and

number of apertural barriers is also important in distinguishing the species in this genus.

Protoconch diameter, teleoconch ribbing and the D/U ratio separate the two new species in *Tristanoropa* gen. nov. Protoconch diameter varied between the two species: *T. hughesae* sp. nov. 410 μ m and *T. conwayensis* sp. nov. a smaller diameter of 330 μ m. However,

TABLE 1. Mean shell measurements of MEQ species examined in this study. New species are designated in bold type.

Taxon	n	D (mm)	H (mm)	UW (mm)	AH (mm)	AW (mm)	PD (mm)	WWB	T1	H/D ratio	D/U ratio	No. whorls	PL
<i>Pereduroopa cursacosta</i>	8	2.36	1.34	0.82	0.94	0.86	0.41	29	50	0.57	2.89	4.17	1.50
<i>Pereduroopa delicata</i>	7	2.01	1.11	0.75	0.85	0.75	0.41	30	73	0.55	2.73	4.39	1.52
<i>Pereduroopa hamiltoniana</i>	6	1.90	1.08	0.64	0.83	0.66	0.41	17	44	0.57	2.97	4.31	1.56
<i>Pereduroopa burwelli</i>	13	2.21	1.24	0.66	0.98	0.83	0.49	37	93	0.56	3.37	4.22	1.66
<i>Isolderopa iangallowayi</i>	14	1.86	1.16	0.70	1.02	0.70	0.33	49	104	0.62	2.68	5.15	1.69
<i>Isolderopa minuta</i>	10	1.41	0.82	0.65	0.70	0.50	0.25	59	124	0.58	2.18	4.42	1.66
<i>Isolderopa deliqua</i>	11	1.95	1.10	0.80	0.91	0.65	0.33	38	100	0.57	2.43	4.41	1.63
<i>Isolderopa teemburra</i>	3	1.97	1.12	0.93	0.87	0.68	0.33	45	119	0.57	2.12	4.42	1.71
<i>Isolderopa whitsunday</i>	11	1.66	0.86	0.70	0.74	0.46	0.33	53	118	0.52	2.40	4.51	1.54
<i>Isolderopa diamante</i>	7	1.55	0.93	0.67	0.82	0.57	0.33	39	108	0.60	2.32	3.98	1.68
<i>Tristanoropa conwayensis</i>	8	1.73	1.02	0.67	0.73	0.63	0.33	35	79	0.59	2.62	4.62	1.53
<i>Tristanoropa hughesae</i>	7	1.66	0.94	0.64	0.76	0.63	0.41	55	109	0.57	2.59	4.74	1.52

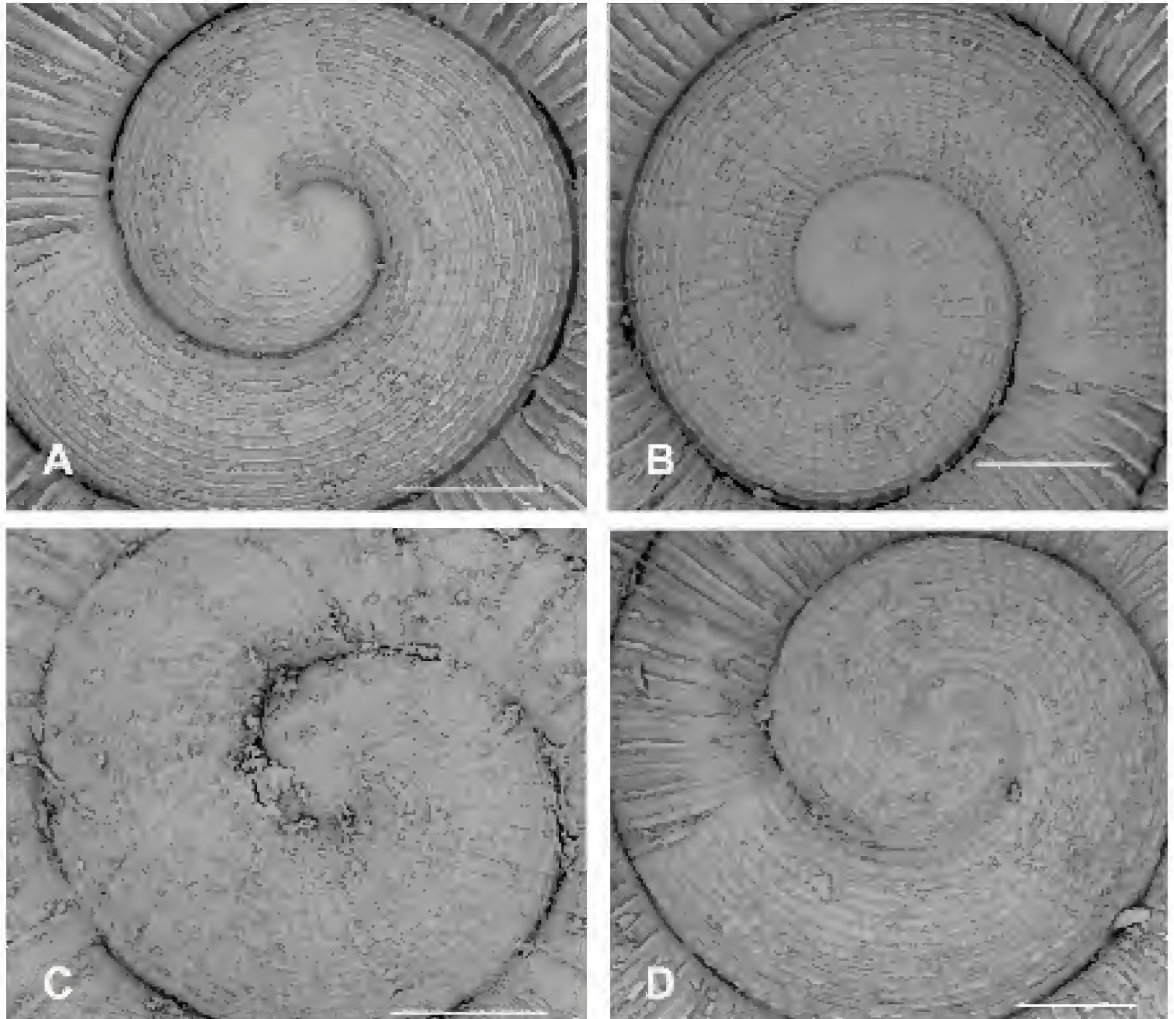


FIG. 4. Protoconch sculpture of *Pereduropa* species. **A**, *P. cursacosta*, QMMO85129, Jaxut SF, MEQ; **B**, *P. delicata*, AMSC154896, Mt Dryander, MEQ; **C**, *P. hamiltoniana*, QMMO86089, Hamilton I., MEQ; **D**, *P. burwelli* sp. nov., QMMO6369, Dalrymple Hts, MEQ. Scale bars = 100 μ m.

the number of ribs on the first whorl of the teleoconch (*T. hughesae* sp. nov. mean 110 ribs, *T. conwayensis* sp. nov. mean 79 ribs) reveals a marked difference between the species.

Shell sculpture. SEM images confirmed that finely cancellate was the baseline protoconch sculptural pattern of all species. A detailed study of the MEQ and other species from the WT and SEQ with finely cancellate protoconchs showed two major variations of this sculpture (Fig. 3): 1, a pattern

where the protoconch exhibited spiral cords only for the first quarter of a whorl followed by these spirals appearing 'bladed' and rising over radial ribs dropping down immediately following the ribs giving the appearance of a 'scalloped' pattern; and 2, a variation was formed by spiral cords and radial ribs of similar heights intersecting to give a netlike appearance. The 'scalloped' variation of a finely cancellate protoconch sculpture was found in each species of the three genera, *Pereduropa*, *Isolderopa* and *Tristanoropa*.

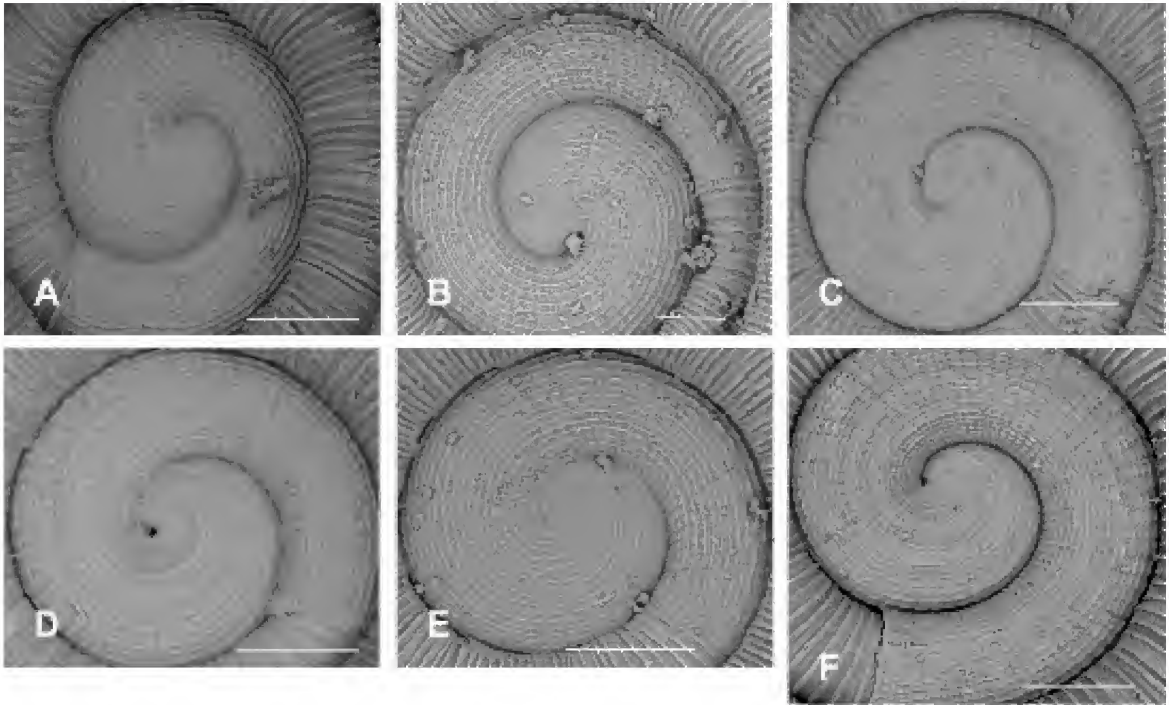


FIG. 5. Protoconch sculpture of *Isolderopa* species. A, *I. iangallowayi*, QMMO85131, Mt Charlton, MEQ; B, *I. minuta*, QMMO78980, Eungella NP, MEQ; C, *I. deliqua*, QMMO78963, Calen-Mt Charlton Rd, MEQ; D, *I. teemburra* sp. nov., QMMO35809, Endeavour Ck, MEQ; E, *I. whitsunday* sp. nov., QMMO11902, Cape Hillsborough, MEQ; F, *I. diamante* sp. nov., QMMO77078, Diamond Cliffs, MEQ. Scale bars = 100 μ m.

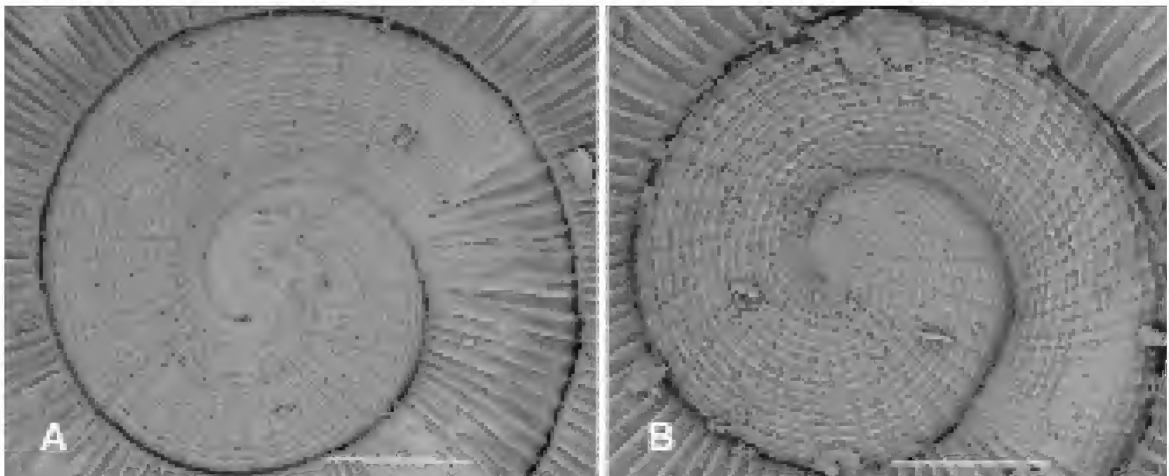


FIG. 6. Protoconch sculpture of *Tristanoropa* gen. nov. species. A, *T. hughesae* sp. nov., QMMO85136, Mt Charlton, MEQ; B, *T. conwayensis* sp. nov., AMSC154891, Brandy Creek, MEQ. Scale bars = 100 μ m.

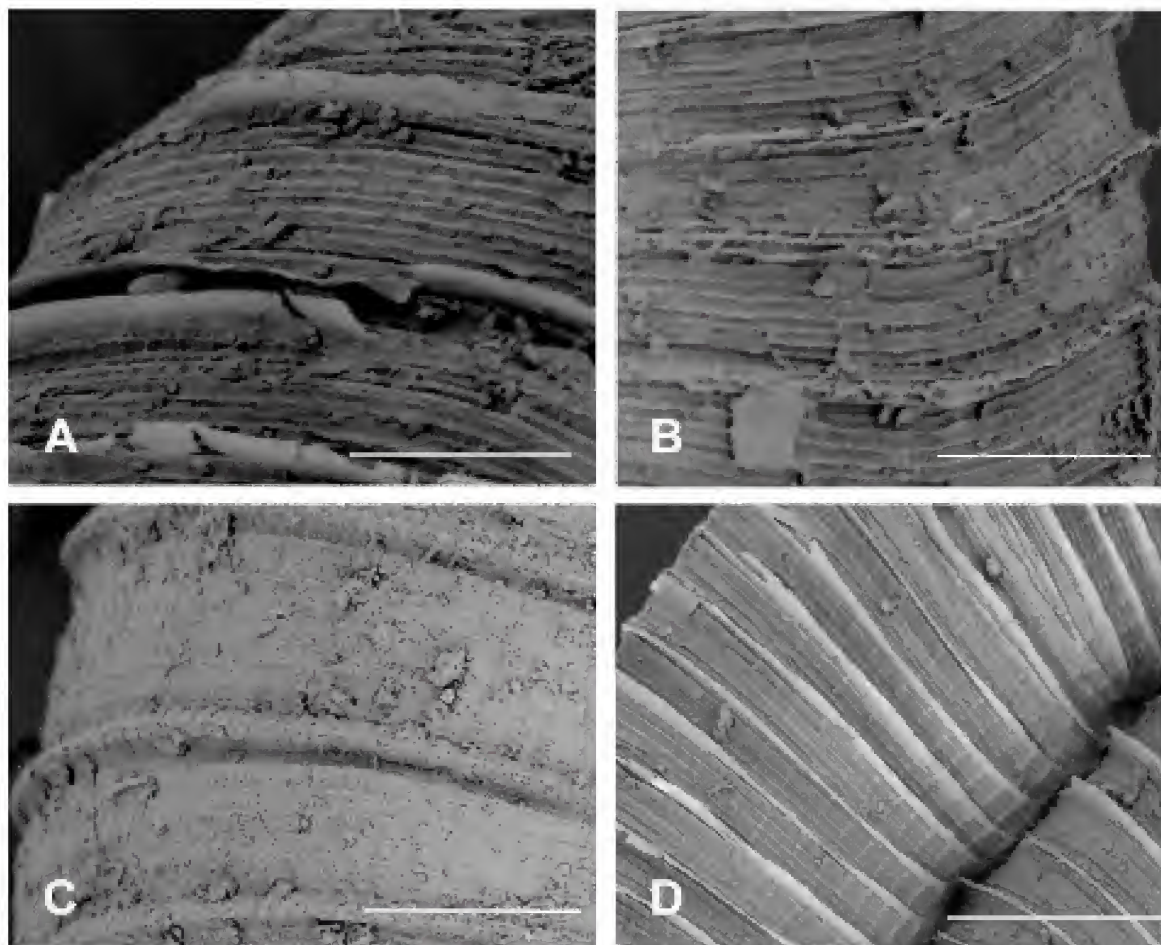


FIG. 7. Teleoconch sculpture of *Pereduropa* species. A, *P. cursacosta*, QMMO11901, Cape Hillsborough, MEQ; B, *P. delicata*, AMSC154896, Mt Dryander, MEQ; C, *P. hamiltoniana*, QMMO86089, Hamilton I., MEQ; D, *P. burwelli* sp. nov., QMMO6374, Broken R., MEQ. Scale bars = 100 μ m. Magnification x800.

Pereduropa species have protoconchs with 17-19 (mean 18) spiral cords with a radial rib distance of 8 to 15 μ m at the end of the first whorl and a distance between the spiral cords and radial ribs. This closer, more numerous ribbing at times forms a 'squamish' pattern on the first whorl, particularly if the specimen is worn. However, stronger spiral cords rise over the finer ribs in a scalloped pattern unlike those with the truly webbed pattern (Fig. 4). *Isolderopa* species also display a scalloped pattern with stronger spiral cords rise over rounded radial

ribbing, but have smaller protoconch diameters than the species of the other two genera and only 12-20 spiral cords (mean 15) with a radial rib distance of 8 to 10 μ m at the end of the first whorl (Fig. 5). The rounded protoconch ribbing appears less distinct than the finer ribbing of *Pereduropa* species. *Tristanoropa* species have a similar pattern with the first quarter of a whorl of spiral cords followed by a strongly scalloped pattern with 17-19 spiral cords (mean 18) and a radial rib distance of 10 μ m (Fig. 6). The *Tristanoropa* scalloped pattern is

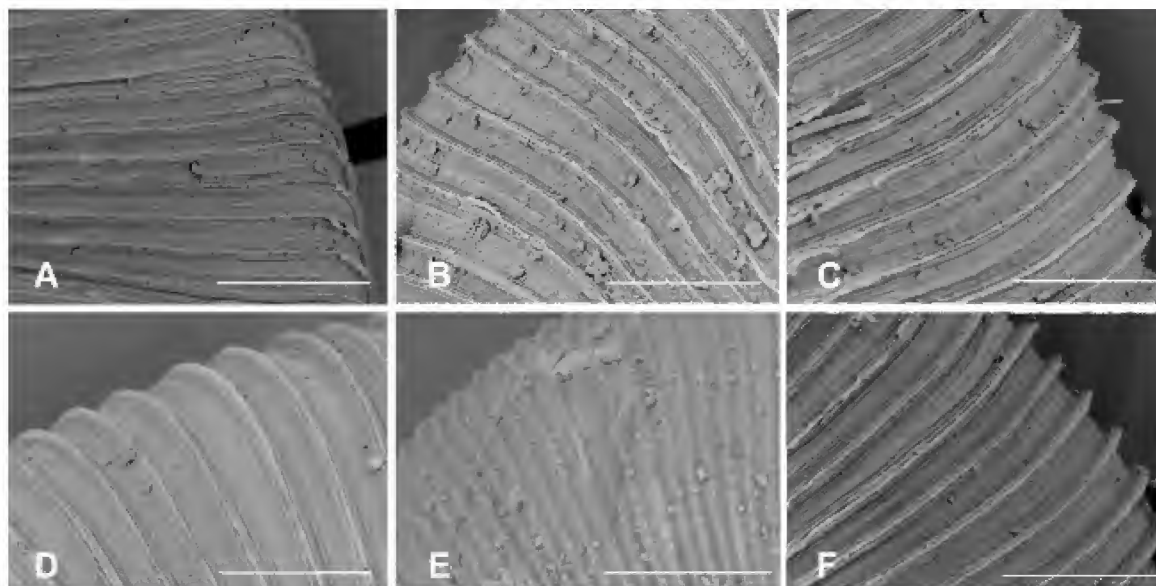


FIG. 8. Teleoconch sculpture of *Isolderopa* species. A, *I. iangallowayi*, QMMO85131, Mt Charlton, MEQ; B, *I. minuta*, QMMO78980, Eungella NP, MEQ; C, *I. deliqua*, QMMO78963, Calen-Mt Charlton Rd, MEQ; D, *I. teemburra* sp. nov., QMMO35809, Endeavour Ck, MEQ; E, *I. whitsunday* sp. nov., QMMO11902, Cape Hillsborough, MEQ; F, *I. diamante* sp. nov., QMMO77078, Diamond Cliffs, MEQ. Scale bars = 100 µm. Magnification x800.

composed of strong spiral cords and strong radial ribs that give a very definite rectangular pattern. While these patterns are similar, the three genera in question can be differentiated by major differences in shell coiling pattern, spire protrusion and the presence of apertural barriers.

Teleoconch sculpture of the twelve species exhibited bladed ribbing in eleven of the species and rounded ribbing in only one, *Pereduropa hamiltoniana* (Figs 7, 8 and 9). The microsculpture of the interstitial radial threads varied in number and size between species. Spiral cords were broad and buttressed against the microradial threads in all species. However, in *Isolderopa* species, the spiral cords were much less defined and appeared missing on the body whorl of *I. minuta*.

Apertural Barriers. Apertural barriers are not present in species of *Pereduropa* or *Tristanoropa*. However, barriers are present in many of the species of *Isolderopa*.

Isolderopa iangallowayi Stanisc, 2010 has an aperture with two vertical palatal barriers (Fig. 10A). *Isolderopa minuta* Stanisc, 2010 has two internal vertical barriers and one parietal barrier (Fig. 10B, C). *Isolderopa whitsunday* sp. nov. has five vertical palatal barriers but no parietal barriers (Fig. 10D). *Isolderopa deliqua* Stanisc, 2010 and *I. teemburra* sp. nov. have no known barriers.

SYSTEMATICS

Pereduropa Stanisc, 2010

Type species. *Pereduropa cursacosta* Stanisc, 2010-by original designation.

Diagnosis. Shell tiny, brown, discoidal with a flat to slightly elevated spire, whorls evenly coiled, sutures impressed; protoconch sculpture finely cancellate consisting of 17-19 scalloped, fine, crisp, crowded spiral cords over weaker radial ribs with a spacing averaging 8-15 m, teleoconch sculpture of crowded radial ribs,

microsculpture of microradial threads and low spiral cords; umbilicus wide V-shaped.

Remarks. *Pereduropa* has a finely cancellate protoconch sculpture similar to that of *Isolderopa* but can be distinguished from the latter genus by other aspects of shell morphology, in particular, the raised spire. *Pereduropa* can be distinguished from *Tristanoropa* gen. nov. by the nautiloid coiling pattern as compared with the multi-whorled pattern of the latter. *Pereduropa* differs from *Shearopa* which has species in SEQ and WT by the lack of apertural barriers.

***Pereduropa cursacosta* Stanislac, 2010**
(Figs 4A, 7A, 11A, 15, Table 1)

Pereduropa cursacosta Stanislac, 2010 in Stanislac *et al.* 2010: 262.

Common Name. Coarse-ribbed Pinwheel Snail.

Materials examined. Holotype. QMMO13082, Bell's Gap, c.15 km S of Sarina, Sarina Range, 21° 31' S, 149° 07' E, nvf, coll. J Stanislac, 7.vii.1982.

Paratype. QMMO78972, 8RC, same data as holotype.

Other material. Cape Hillsborough NP: QMMO11901, 3RC; ; Hatfield's Gap: QMMO19993, 1RC; Mackay-Seaforth Rd: QMMO13473, 1RC; Mt Macartney: QMMO59649, 1RC; Nebo-Mackay Rd: QMMO85133, 5RC; Nth Mackay, Hicks Rd: QMMO85127, 4RC.

Diagnosis. Shell tiny, mean diameter 2.35 mm, with a slightly elevated spire, mean shell height 1.33 mm; protoconch finely cancellate with 17 scalloped spiral cords, mean radial rib spacing 10 µm, diameter 410 µm; teleoconch with 44–72 (mean 55) radial ribs on first whorl; wide V-shaped umbilicus, mean D/U ratio 2.87.

Description. Shell tiny, brown, discoidal with a slightly elevated spire, whorls 4.0–4.5 evenly coiled, sutures impressed; diameter of shell 2.13–2.54 mm, height 1.23–1.48 mm, H/D 0.53–0.62 (mean 0.57). Protoconch flat, 1.5 whorls with a diameter of 410 µm sculptured with a scalloped finely cancellate pattern consisting of fine, crisp, crowded spiral cords and widely spaced, weak radial ribs; teleoconch sculpture of bladed, crowded radial ribs 44–60 on first whorl, microsculpture of microradial threads and low, broad spiral cords; umbilicus wide V-shaped, diameter 0.74–0.90 mm, D/U 2.70–

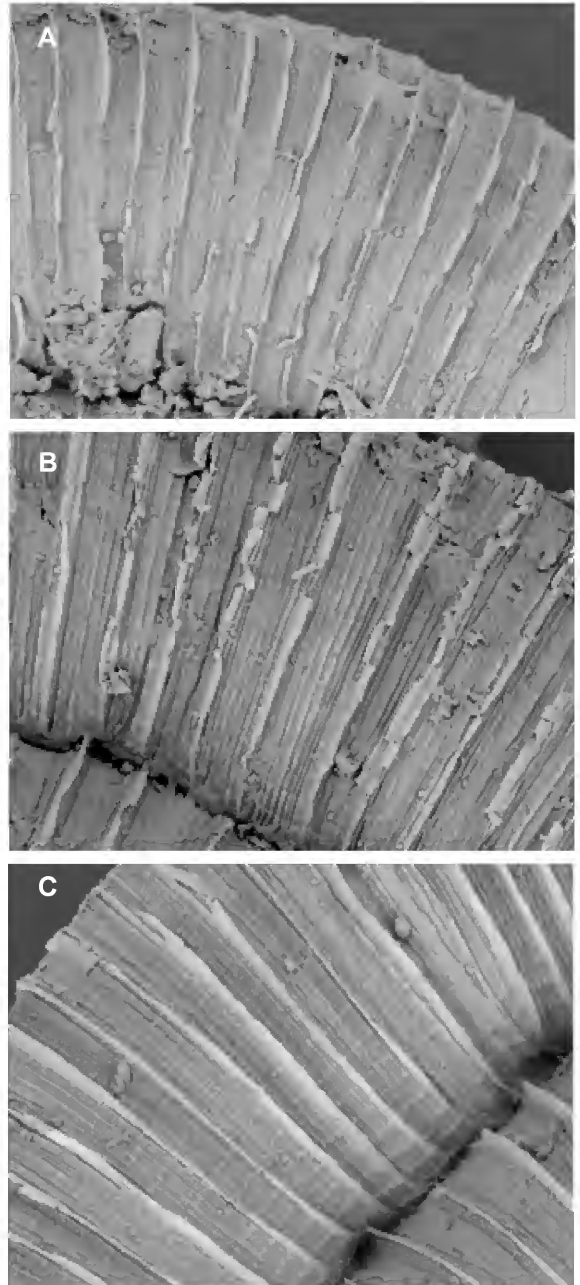


FIG. 9. Teleoconch sculpture of *Tristanoropa* gen. nov. species. **A**, *T. hughesae* sp. nov., QMMO50905, Eungella NP, MEQ; **B**, *T. conwayensis* sp. nov., AMSC154891, Brandy Creek, MEQ. Scale bars = 100 µm. Magnification x800.

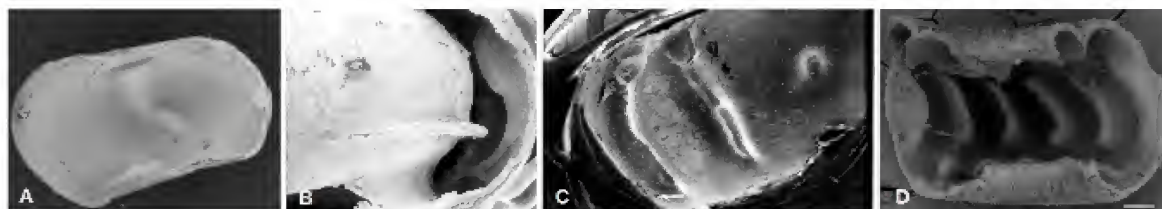


FIG. 10. Barriers in *Isolderopa* species. **A**, Palatal barriers in *I. iangallowayi*, QMMO78962, Mt Charlton, MEQ; **B**, Parietal barrier in *I. minuta*, QMMO9737, Broken R., MEQ; **C**, Palatal barriers in *I. minuta*, QMMO9726, Eungella NP, MEQ; **D**, Multiple palatal barriers of *I. whitsunday*, QMMO74081, Long I, MEQ. Images B, C: John Stanisic, QM.

3.30 (mean 2.89). Based on 8 measured adult specimens.

Distribution and habitat. Mackay-Sarina hinterland, MEQ, in rainforest and vine thicket; living under logs and other forest debris, in litter.

Remarks. *Pereduropa cursacosta* differs from *P. delicata* and *P. burwelli* sp. nov. in having coarser, more widely spaced ribs on the teleoconch. *Pereduropa cursacosta* differs from *P. hamiltoniana* by having bladed ribs on the teleoconch in contrast to the rounded ribs of the latter.

***Pereduropa delicata* Stanisic, 2010**
(Figs 4B, 7B, 11B, 15, Table 1)

Pereduropa delicata Stanisic, 2010 in Stanisic *et al.* 2010: 262.

Common Name. Delicate-ribbed Pinwheel Snail.

Material examined. Holotype. QMMO13090, c.19 km N of Proserpine, beside Gregory R., 20°17'S, 148°35'E, nvf, coll. J. Stanisic, 6.vii.1982.

Paratypes. QMMO35547, 2RC, Mt Dryander, lower slopes, via Gregory, NE Proserpine, 20°17' S, 148° 35' 30" E, coll. J. Stanisic, D. Potter, N. Potter, 16.v.1990; QMMO78971, 7RC, ca. 19k N. of Proserpine, beside Gregory R., 20° 17' S, 148° 35' E, coll. J. Stanisic, 6.vii.1982.

Other material. Mt Dryander: QMMO31293, 1SC; AMSC154896, 9RC; QMMO35562, 1SC.

Diagnosis. Shell tiny, mean diameter 2.01 mm, with flat to a slightly elevated spire, mean shell height 1.11 mm; protoconch finely cancellate with 19 scalloped spiral cords, mean radial rib spacing 15 µm, diameter 410 µm; teleoconch with 62–91 (mean 75) radial ribs on first whorl; umbilicus wide V-shaped, mean D/U ratio 2.76.

Description. Shell tiny, brown, discoidal with a flat to slightly raised spire, whorls 4.0–4.875 evenly coiled, sutures impressed; diameter of shell 1.72–2.21 mm (mean 2.01 mm), height 0.98–1.23 mm (mean 1.1 mm), H/D 0.48–0.58 (mean 0.55). Protoconch flat, 1.5–1.625 whorls with a diameter of 410 µm sculptured with a scalloped finely cancellate pattern consisting of fine, crisp, crowded spiral cords and widely spaced, rounded radial ribs; teleoconch sculpture of bladed, crowded radial ribs 62–82 (mean 73) on first whorl, microsculpture of microradial threads and low, broad spiral cords; umbilicus wide V-shaped, diameter 0.57–0.90 mm (mean 0.75 mm), D/U 2.27–3.57 (mean 2.73). Based on 7 measured adult specimens.

Distribution and habitat. Mackay-Proserpine, MEQ; rainforest living in litter.

Remarks. *Pereduropa delicata* is distinguished from *P. cursacosta* and *P. hamiltoniana* by having a higher mean value of ribs on the teleoconch than the latter two but differs from *P. burwelli* sp. nov. by having less ribs on the teleoconch. The mean protoconch diameter of *P. delicata* (410 µm) differs from that of *P. burwelli* (490 µm) and *I. diamante* (330 µm).

***Pereduropa hamiltoniana* Stanisic, 2010**
(Figs 4C, 7C, 11C, 15, Table 1)

Pereduropa hamiltoniana Stanisic, 2010, in Stanisic *et al.* 2010: 262.

Common Name. Hamilton Island Pinwheel Snail.

Materials examined. Holotype. QMMO65834, Hamilton I., c.2.5 km N of main resort on E side, Whitsunday Group, 20°20'23"S, 148°57'24"E, *Araucaria*/vine thicket, coll. J. Stanisic, J. Chaseling, 26.vi.1999.

Paratypes. QMMO60585, 1RC, Whitsunday Group, Whitsunday I, 20° 18' S, 149° 3' 30" E, coll. J. Stanicic, 2.x.1996; QMMO78970, 6RC, same data as holotype.

Other material. Hamilton I.: QMMO86089, 2RC. Gloucester I.: QMMO74109, 1RC.

Diagnosis. Shell tiny, mean diameter 1.9 mm, with a flat to slightly raised slightly elevated spire, mean shell height 1.33 mm; protoconch finely cancellate with 19 scalloped spiral cords and radial ribs 15 µm apart, diameter 410 µm; teleoconch with mean 43 radial ribs on first whorl and more widely spaced teleoconch on the body whorl; umbilicus wide V-shaped, mean D/U ratio 2.97.

Description. Shell minute, orange-brown, discoidal with a flat to slightly raised spire, whorls 4.25–4.375 evenly coiled, sutures impressed; diameter of shell 1.8–2.05 mm (mean 1.9 mm), height 0.98–1.08 mm (mean 1.08 mm); H/D 0.52–0.61 (mean 0.57). Protoconch flat, 1.50–1.625 whorls with a diameter 410 µm sculptured with a scalloped finely cancellate pattern consisting of fine, crisp, crowded spiral cords and widely spaced, weak radial ribs; teleoconch sculpture of rounded, crowded radial ribs 42–45 (mean 43) on first whorl, microsculpture of microradial threads and low spiral cords; umbilicus wide V-shaped, diameter 0.57–0.74 mm (mean 0.64 mm). D/U 2.78–3.29 (mean 2.97). Based on 6 measured adult specimens.

Distribution and habitat. Whitsunday islands, MEQ; rainforest and vine thicket living in litter.

Remarks. *Pereduropa hamiltoniana* is distinguished from *P. cursacosta* and *P. delicata* by having a more elevated spire and more widely spaced ribs on the teleoconch. *P. hamiltoniana* differs from other *Pereduropa* species by having rounded, as opposed to bladed, ribs on the teleoconch and a smaller aperture width. The drier coastal rainforests of the off-lying islands of MEQ, which receive an annual average rainfall of 1600 mm (Bureau of Meteorology 2017), support this species which has not yet been found on the mainland.

***Pereduropa burwelli* sp. nov.**
(Figs 4D, 7D, 11D, 15, Table 1)

Etymology. Named for Queensland Museum entomologist Dr Chris Burwell.

Preferred common name. Burwell's Pinwheel Snail.

Materials examined. Holotype. QMMO6372, Eungella NP, Dalrymple Heights, 21° 2'S, 148° 36'E, coll. M. Bishop, xi.1976. Diameter 2.21 mm, height 1.31 mm, H/D 0.59, D/U 4.5, number of whorls 4.375.

Paratype. QMMO6369, 10RC, same data as holotype.

Other material. Eungella NP: QMMO85071, 1 RC; QMMO85103, 1 RC; QMMO85105, 1 RC; QMMO6374, 1RC; QMMO86550, 12RC; QMMO11759, 1RC; QMMO42392, 1RC; QMMO85084, 1RC; QMMO85170, 1RC; QMMO85171, 1RC. Dalrymple Heights: AMSC154899, 1RC. Mt William: AMSC154908, 1RC. Crediton Creek: QMMO6355, 3RC; QMMO85177, 8RC; QMMO13075, 5RC. Finch Hatten NP: QMMO6365, 1RC; QMMO85075, 1RC; AMSC151906, 1RC.

Diagnosis. Shell tiny, mean diameter 2.21 mm with a flat to slightly elevated spire, mean shell height 1.24 mm; protoconch finely cancellate with 18 scalloped spiral cords, mean radial rib spacing 15 µm, protoconch diameter 490 µm; teleoconch with mean 93 radial ribs on first whorl; umbilicus wide V-shaped, D/U 3.37.

Description. Shell tiny, brown, discoidal with a flat to slightly raised spire, whorls 4.0–4.375 evenly coiled, sutures impressed; diameter of shell 2.05–2.54 mm (mean 2.21 mm), height 1.15–1.48 mm (mean 1.24 mm), H/D 0.50–0.62 (mean 0.56). Protoconch flat, 1.50–1.875 whorls with a diameter of 490 µm sculptured with a scalloped finely cancellate pattern consisting of fine, crisp, crowded spiral cords and widely spaced, weak radial ribs; teleoconch sculpture of bladed, very crowded radial ribs 78–116 (mean 101) on first whorl, microsculpture of microradial threads and low spiral cords; umbilicus wide V-shaped, diameter 0.49–0.74 mm (mean 0.66 mm), D/U 2.89–4.50 (mean 3.37). Based on 15 measured adult specimens.

Distribution and habitat. Eungella NP, MEQ; rainforest and vine thicket living in litter.

Remarks. *Pereduropa burwelli* now named is distinguished from its congeners by having a larger protoconch diameter, more finely spaced

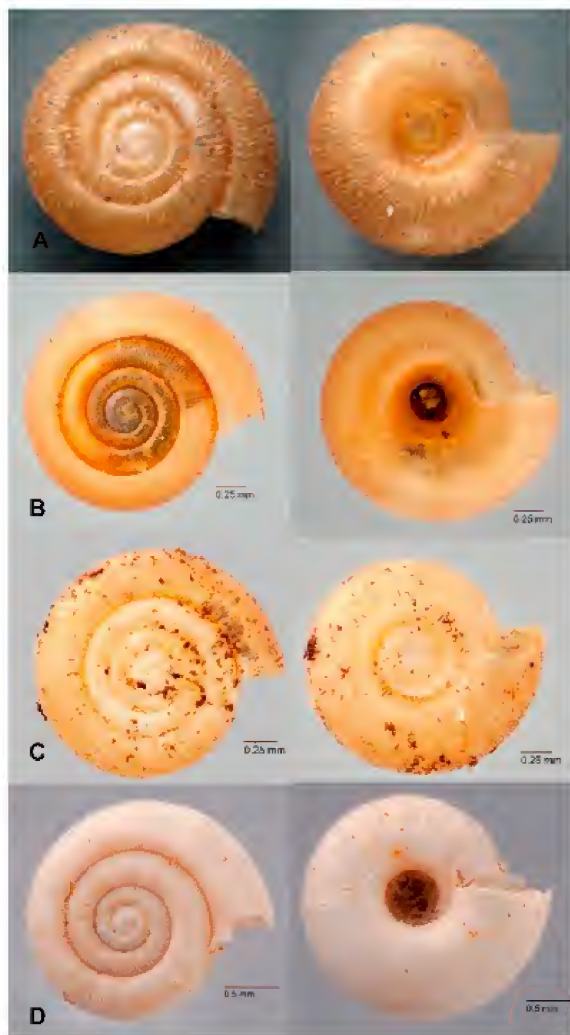


FIG. 11. Dorsal and ventral views of holotypes of *Pereduropa* species. A, *P. cursacosta*, QMMO13082, Bell's Gap, MEQ; B, *P. delicata*, QMMO13090, N of Proserpine, MEQ; C, *P. hamiltoniana*, QMMO65834, Hamilton I, MEQ; D, *P. burwelli* sp. nov., QMMO6732, Dalrymple Hts, MEQ. Images A: John Stanisic; B-D: Geoff Thompson, QM.

ribs on the teleoconch and a much larger D/U ratio (Table 1). *Pereduropa burwelli* is one of the larger *Pereduropa* species and appears to be restricted to the moist rainforests of Eungella NP in the Clarke Range. With an annual rainfall of around 2300 mm (Bureau of Meteorology

2017), the Eungella plateau rises to an altitude of 1259 m at Mt Dalrymple. *Pereduropa burwelli* is not known at altitudes below the upper reaches of Crediton Ck and Finch Hatton Gorge (606 m) and is distinguished from *P. cursacosta* which has been found at lower altitudes by much finer ribbing on the teleoconch.

Isolderopa Stanisic, 2010

Type species. *Isolderopa iangallowayi* Stanisic, 2010-by original designation.

Diagnosis. Shell tiny, brown, biconcave with a depressed to very depressed spire, whorls tightly coiled; protoconch sculpture finely cancellate consisting of 12 – 17 scalloped, fine, crisp, crowded spiral cords and widely spaced, strong radial ribs with a spacing averaging 10 µm; teleoconch sculpture of densely crowded radial ribs, microsculpture of microradial threads and low spiral cords; aperture usually with barriers, palatal barriers when present, vertical; umbilicus wide V-shaped to wide cup-shaped.

Remarks. The combination of a strongly sunken spire with more prominent apical spiral cords and vertical palatal barriers distinguishes *Isolderopa* from *Shearopa*, *Tristanoropa* gen. nov. and *Pereduropa*. Furthermore, *Isolderopa* is also distinguished from *Tristanoropa* gen. nov. by its nautiloid coiling pattern compared with the multi-whorled pattern of the latter.

Isolderopa iangallowayi Stanisic, 2010 (Figs 5A, 8A, 12A, 16, Table 1)

Isolderopa iangallowayi Stanisic, 2010 in Stanisic *et al.* 2010: 260.

Common name. Galloway's Pinwheel Snail.

Materials examined. Holotype. QMMO13102, c.17.5 km SW of Calen, on Calen Mt Charlton Road, 21°00' S, 148°42' E, nvf, coll. J Stanisic, 6.vii.1982.

Paratypes. QMMO50880, 8RC, Eungella NP, Rocky Ck, 20° 54'S, 148° 36'E, coll. ANZES, 29.xii.1993; QMMO78962, 17RC, same data as holotype.

Other material. Eungella NP: QMMO50885, 7RC; QMMO59641, 1RC; QMMO85116, 1SC; QMMO50891, 1RC; QMMO85076, 1 RC; QMMO85345, 3SC; QMMO86088, 2RC; Mt Charlton: QMMO85131, 11RC; Mt Dalrymple: QMMO36094, SC6; Mt Macartney: QMMO35633, SC7; QMMO35634, SC1; Mt Vince: AMSC140446, 3RC; Pelion SF: QMMO85082, 1 RC.

Diagnosis. Shell tiny, golden-brown, mean diameter 1.86 mm, biconcave with a deeply depressed spire, mean shell height 0.82 mm, very tightly coiled and laterally compressed; protoconch finely cancellate with 13–16 scalloped spiral cords, mean radial rib spacing 10 µm, protoconch diameter 330 µm; teleoconch with mean 104 radial ribs on the first whorl; aperture with 2 vertical internal palatal barriers; umbilicus deep V-shaped, mean D/U ratio 2.68.

Description. Shell tiny, golden-brown, biconcave with a very deeply sunken spire, whorls 4.875–5.375 very tightly coiled and laterally compressed, sutures impressed; diameter of shell 1.56–2.13 mm (mean 1.86 mm), height 1.07–1.23 mm (mean 1.16 mm); H/D 0.58–0.74 (mean 0.62). Protoconch flat, 1.50–1.75 whorls with a diameter of 330 µm sculptured with a scalloped finely cancellate pattern consisting of fine, crisp, crowded spiral cords and widely spaced, strong radial ribs; teleoconch sculpture of bladed, crowded radial ribs 88–120 (mean 104) on first whorl, microsculpture of microradial threads and low spiral cords; aperture with 2 internal vertical palatal barriers; umbilicus wide, deep V-shaped, diameter 0.66–0.74 mm (mean 0.7 mm). D/U 2.44–3.0 (mean 2.68). Based on 14 measured adult specimens.

Distribution and habitat. Eungella NP and Mt Charlton, MEQ; rainforest living in litter.

Remarks. *Isolderopa iangallowayi* is distinguished from *Pereduropa* species and *Tristanoropa* species by the combination of a very deeply sunken spire, very tightly coiled whorls and V-shaped umbilicus. The two vertical palatal barriers and more numerous whorls separates *I. iangallowayi* from other *Isolderopa* species.

***Isolderopa minuta* Stanisic 2010**
(Figs 5B, 8B, 12B, 16, Table 1)

Isolderopa minuta Stanisic, 2010 in Stanisic *et al.* 2010: 260.

Common name. Golden Goblet Pinwheel Snail.

Materials examined. Holotype. QMMO13445, Broken R, Eungella NP, 21°10' S, 148°30' E, nvf, coll. J. Stanisic, 5.vii.1982.

Paratypes. QMMO9368, 12RC, Eungella NP, Dalrymple Heights, 21° 2' S, 148° 36' E, 1000 m, coll.

M. Bishop, xi.1976; QMMO9726, 10RC, Crediton Ck, Eungella NP, 21°11' S, 148° 32' E, 850 m, coll. M. Bishop, xi.1976; QMMO9737, 6RC, Eungella NP, Broken R, 21°10' S, 148°30' E, 800m, coll. M. Bishop, xi.1976; QMMO13072, 4RC, Diggings Rd, Eungella NP, 21° 9' S, 148° 29' E, coll. J. Stanisic, 8.vii.1982; QMMO50886, 7 RC, Eungella NP, Rocky Ck, 20° 54' S, 148°36' E, coll. ANZES, 29.xii.1993; QMMO50904, 4RC, Eungella NP, 20°52' S, 148°37' E, coll. ANZES, 28.xii.1993; QMMO78980, 5RC, same data as holotype.

Other material. Bells Gap: QMMO13083, 2RC; Calen - Mt Charlton Rd: QMMO13100, 4RC; Crediton Ck: QMMO59543, 1SC, AMSC154907, 4RC; Eungella NP off Eungella Dam Rd: QMMO85114, 1SC; Eungella NP, Broken River: QMMO59643, 3 RC; Eungella NP, Entrance/lookout: QMMO85137, 5RC; Eungella NP, Finch Hatton Gorge: QMMO85066, 2RC; QMMO85072, 1RC; QMMO85085, 3RC; QMMO85087, 1RC; QMMO85099, 2RC; Eungella NP, Mt Dalrymple: QMMO50879, 1RC; QMMO85077, 1RC; QMMO85078, 10RC, QMMO85081, 3RC; QMMO85088, 1 RC; QMMO85093, 1RC; QMMO85094, 1 RC; QMMO85097, 2RC; QMMO85100, 1RC; Eungella NP, Mt Henry: QMMO85068, 1RC; QMMO85106, 2RC; Eungella NP, Mt William: QMMO85070, 1RC; AMSC154905, 2RC.

Diagnosis. Shell minute, brown, mean diameter 1.41 mm, biconcave with a deeply depressed spire, mean shell height 0.82 mm, tightly coiled laterally compressed; protoconch finely cancellate with 12–16 scalloped spiral cords, mean radial rib spacing 10 µm, protoconch diameter 250 µm; teleoconch with mean 124 crowded, radial ribs on first whorl; aperture with several internal vertical, palatal barriers and one parietal barrier; umbilicus wide saucer-shaped, mean D/U 2.18.

Description. Shell minute, brown, biconcave with a very deeply sunken spire, whorls 4.25–4.75 very tightly coiled and laterally compressed, sutures impressed; diameter of shell 1.23–1.64 mm (mean 1.41 mm), height 0.74–0.90 mm (mean 0.82 mm), H/D 0.53–0.63 (mean 0.58). Protoconch flat, 1.5–1.75 whorls with a diameter of 250 µm sculptured with a scalloped finely cancellate pattern consisting of fine, crisp, crowded spiral cords and widely spaced, strong radial ribs; teleoconch sculpture of bladed, crowded radial ribs 112–129 (mean 124) on first whorl, microsculpture of microradial threads and low spiral cords; aperture with several internal, vertical palatal barriers and one parietal lamella; umbilicus wide saucer-shaped; diameter 0.57–

0.74 mm (mean 0.65 mm), D/U 2.00–2.29 (mean 2.18). Based on 10 measured adult specimens.

Distribution and habitat. Eungella environs and the Clarke Ra., MEQ; rainforest living in litter.

Remarks. *Isolderopa minuta* differs from all other *Isolderopa* species by its small shell diameter, a minute protoconch diameter of 250 µm and in having a parietal lamella as well as vertical palatal barriers. *Isolderopa minuta* differs from *I. iangallowayi* by having a less depressed spire and much wider umbilicus. The Eungella plateau, home to *I. minuta*, rises to an altitude of 1259 m at Mt Dalrymple where the species has been collected at 1234 m. The species has also been collected from lower altitudes at Broken River (alt. 800 m) and Finch Hatton Gorge (alt. 400 m).

***Isolderopa deliqua* Stanisic, 2010**
(Figs 5C, 8C, 12C, 16, Table 1)

Isolderopa deliqua Stanisic, 2010 in Stanisic *et al.* 2010: 260.

Preferred common name. Calen Pinwheel Snail formerly known as the Whitsunday Pinwheel Snail.

Materials examined. Holotype. QMMO13101, c.17.5 km SW Calen, on Calen–Mt Charlton Rd, 21°00' S, 148°42' E, nvf, coll. J. Stanisic, 6.vii.1982.

Paratypes. QMMO9725, 13RC, Eungella NP, Broken R, 21° 10' S, 148° 30' E, 800 m, coll. M. Bishop, xi.1976; QMMO13452, 19RC, Eungella NP, Broken R, 21° 10' S, 148° 30' E, coll. J. Stanisic, 5.vii.1982; QMMO78963, 5RC, same data as holotype; QMMO6354, 20RC, Crediton Ck, Eungella NP, 21° 11' S, 148° 32' E, coll. M. Bishop, xi.1976; QMMO78960, 4RC, Eungella NP, Broken R, 21° 10' S, 148° 30' E, coll. J. Stanisic, 5.vii.1982.

Other material. Crediton Ck: QMMO59544, 3SC. Eungella NP: QMMO50909, 1RC; QMMO6378, 1SC. Mt Charlton: QMMO85132, 1RC.

Diagnosis. Shell tiny, brown, mean diameter 1.95 mm, biconcave with a depressed spire, mean shell height 1.95 mm, very tightly coiled with a shallow sulcus on the upper half of body whorl of adults; protoconch finely cancellate with 17–19 scalloped spiral cords, mean radial rib spacing 10 µm, protoconch diameter 330 µm; teleoconch with mean 100 radial ribs on first whorl; umbilicus wide V-shaped, mean D/U ratio 2.43.

Description. Shell tiny, brown, biconcave with a depressed spire, whorls 4.125–4.75 tightly coiled with a shallow sulcus on upper half of body whorl in adults, sutures impressed; diameter of shell 1.64–2.21 mm (mean 1.95 mm), height 0.90–1.15 mm (mean 1.1 mm); H/D 0.52–0.68 (mean 0.57). Protoconch flat, 1.50–1.75 whorls with a diameter of 330 µm sculptured with a scalloped finely cancellate pattern consisting of fine, crisp, crowded spiral cords and widely spaced, strong radial ribs; teleoconch sculpture of bladed, densely crowded radial ribs 87–115 on first whorl, microsculpture of microradial threads and low spiral cords; aperture with no barriers; umbilicus saucer-shaped; diameter 0.74–0.82 mm (mean 0.80 mm). D/U 2.00–2.78 (mean 2.43). Based on 11 measured adult specimens.

Distribution and habitat. Eungella NP and Mt Charlton area, MEQ; rainforest and vine thicket living in litter.

Remarks. *Isolderopa deliqua* is distinguished from *I. iangallowayi*, *I. minuta*, and *I. whitsunday* sp. nov. by its lack of apertural barriers. *Isolderopa deliqua* differs from *I. teemburra* sp. nov. and *I. diamante* sp. nov. in having fewer ribs on the teleoconch and a higher D/U ratio. *Isolderopa teemburra* sp. nov. and *I. diamante* sp. nov. are endemic to a small area of the Endeavour Creek in Crediton SF and the Diamond Cliffs in Homevale NP, respectively, whereas *I. deliqua* is found across the rainforests of the higher altitudes of the Eungella plateau above 800 m and the Mt Charlton area. Stanisic *et al.* (2010) placed this species in *Isolderopa* with reservations. However, detailed morphological examination confirms this species as a member of the genus.

***Isolderopa teemburra* sp. nov.**
(Figs 5D, 8D, 12D, 16, Table 1)

Etymology. Named for Teemburra Creek which is the major creek into which Endeavour Creek, the type locality, flows.

Preferred common name. Teemburra Pinwheel Snail.

Materials examined. QMMO35809, Endeavour Ck, Upper Reaches, Clarke Ra, W of Mackay, 21° 15' 30" S, 148° 37' 30" E, coll. J. Stanisic, D. Potter, N.

Potter, 20.v.1990. Diameter 2.05 mm, height 1.23 mm, H/D 0.60, D/U 2.27, number of whorls 4.375.

Paratypes. QMMO86547, 5SC/15RC, same data as holotype.

Other material. Cherry Tree Creek: QMMO85339, 1SC.

Diagnosis. Shell tiny, brown, mean diameter 1.97 mm, biconcave with a depressed spire, mean shell height 1.12 mm, tightly coiled laterally compressed; protoconch finely cancellate with 15–16 scalloped spiral cords, mean radial rib spacing 10 µm, protoconch diameter 330 µm; teleoconch with mean 119 very crowded, radial ribs on first whorl; umbilicus saucer-shaped, mean D/U 2.12.

Description. Shell tiny, brown, biconcave with a depressed spire, whorls 4.375–4.50 very tightly coiled and laterally compressed, sutures impressed; diameter of shell 1.89–2.05 mm (mean 1.97 mm), height 1.07–1.23 mm (mean 1.12 mm), H/D 0.54–0.60 (mean 0.57). Protoconch flat, 1.625–1.75 whorls with a diameter of 330 µm sculptured with a scalloped finely cancellate pattern consisting of fine, crisp, crowded spiral cords and widely spaced, rounded radial ribs; teleoconch sculpture of bladed, very densely crowded radial ribs 110–125 (mean 119) on first whorl, microsculpture of microradial threads and low spiral cords; aperture with no barriers; umbilicus wide, saucer-shaped, diameter 0.90–0.98 mm (mean 0.93 mm), D/U 2.00–2.27 (mean 2.12). Based on 3 measured adult specimens.

Distribution and habitat. Endeavour Creek and Cherry Tree Creek, both tributaries of Teemburra Creek in Crediton SF and Finch Hatton Gorge, MEQ; rainforest living in litter.

Remarks. *Isolderopa teemburra* is distinguished from most other *Isolderopa* species, with the exception of *I. deliqua* and *I. diamante* sp. nov., by having no apertural barriers. *Isolderopa teemburra* can be distinguished from *I. deliqua* by having finer teleoconch ribbing, 4–5 microradial ribs versus 6–7 microradial ribs in the latter, a much wider umbilicus and lower D/U ratio. *Isolderopa teemburra* has been found at Finch Hatton Gorge at an altitude of 244 m, and Endeavour Creek and Cherry Tree Creek in the lower altitudes of Crediton State Forest, MEQ (alt. 575 m).

Isolderopa whitsunday sp. nov.

(Figs 5E, 8E, 12E, 16, Table 1)

Etymology. Named for the Whitsunday Bioprovince.

Preferred common name. Whitsunday Pinwheel Snail.

Materials examined. Holotype: QMMO13089, c. 19k N. of Proserpine, beside Gregory R., 20° 17'S, 148° 35'E, coll. J. Stanicic, 6.vii.1982. Diameter 1.56 mm, height 0.9 mm, H/D 0.58, D/U 2.38, number of whorls 4.5.

Paratype. QMMO86548, 12RC, same data as holotype.

Other material. Brandy Ck SF: QMMO86565, 1RC; AMSC154890, 22RC. Cape Hillsborough NP: QMMO11902, 11RC; QMMO59642, 1RC. c.45 km N Mackay. Hamilton I: QMMO65835, 1RC; QMMO86073, 2RC. Long I: QMMO74081, 2RC. Mt Dryander: QMMO35548, 4RC; AMSC154892, 1RC; AMSC154895, 10RC; QMMO60586, 4RC. Mackay-Seaforth Road: QMMO13474, 1RC. Conway Range NP: QMMO85125, 1RC; QMMO85333, 1SC. Jaxut SF: QMMO85128, 15RC; Proserpine: QMMO68647, 16RC. West Molle I.: QMMO6348; QMMO86549, 5RC.

Diagnosis. Shell tiny, golden-brown, mean diameter 1.66 mm, biconcave with a depressed spire, mean shell height 0.86 mm, tightly coiled, laterally compressed; protoconch finely cancellate with 12–16 scalloped spiral cords, mean radial rib spacing 10 µm, protoconch diameter 330 µm; teleoconch with mean 118 crowded, radial ribs on first whorl; mean aperture height 0.74 mm; aperture with five internal vertical, palatal barriers; umbilicus wide saucer-shaped, mean D/U 2.40.

Description. Shell tiny, golden-brown, biconcave with a depressed spire, whorls 4.125–5.0 tightly coiled with a shallow sulcus on upper half of body whorl in adults, sutures impressed; diameter of shell 1.48–2.05 mm (mean 1.66 mm), height 0.82–0.90 mm (mean 0.86 mm), H/D 0.44–0.58 (mean 0.52). Protoconch flat, 1.50–1.625 whorls with a diameter of 330 µm sculptured with a scalloped finely cancellate pattern consisting of fine, crisp, crowded spiral cords and widely spaced, strong radial ribs; teleoconch sculpture of bladed, very densely crowded radial ribs 108–130 (mean 118) on first whorl, microsculpture of microradial threads and low spiral cords; aperture with five vertical palatal barriers; umbilicus wide, saucer-shaped; diameter 0.66–0.74 mm (mean

0.70 mm), D/U 2.09–2.75 (mean 2.40). Based on 18 measured adult specimens.

Distribution and habitat. Mackay-Proserpine area, Cape Hillsborough and off lying Whitsunday islands, MEQ; rainforest and vine thicket living in litter.

Remarks. *Isolderopa whitsunday* sp. nov. is distinguished from other *Isolderopa* species by having five vertical palatal barriers and no parietal barriers. *Isolderopa whitsunday* has very crowded teleoconch ribbing similar to that in *I. minuta* but differs from that species in its larger shell diameter, larger protoconch width and higher mean D/U ratio.

Isolderopa diamante sp. nov.
(Figs 5F, 8F, 12F, 16, Table 1)

Etymology. From the French *diamant* = diamond, referring to the type locality.

Preferred common name. Diamond Cliffs Pinwheel Snail.

Material examined. Holotype. QMMO86546, Mackay, WSW at Diamond Cliffs, Homevale NP, 21° 22' 59"S, 148° 34' 21"E, coll. QM party, 14.x.2005. Diameter 1.56 mm, height 0.90 mm, H/D 0.58, D/U 2.38, number of whorls 4.

Paratypes. QMMO77078, 100RC, same data as holotype.

Diagnosis. Shell tiny, mean diameter 1.55 mm with a depressed spire, mean shell height 0.93 mm; protoconch finely cancellate with 18 scalloped spiral cords, mean radial rib spacing 8 µm, protoconch diameter 330 µm; teleoconch with mean 108 radial ribs on first whorl; umbilicus wide V-shaped, mean D/U 2.32.

Description. Shell tiny, pale brown, discoidal with a depressed spire, whorls 3.75–4.25 evenly coiled, sutures impressed; diameter of shell 1.39–1.62 mm (mean 1.55 mm), height 0.82–1.15 mm (mean 0.93 mm), H/D 0.56–0.67 (mean 0.6). Protoconch flat, 1.50–1.75 whorls with a diameter of 330 µm sculptured with a scalloped finely cancellate pattern consisting of fine, crisp, crowded spiral cords and widely spaced, weak radial ribs; teleoconch sculpture of bladed, very crowded radial ribs 102–117 (mean 108) on first whorl, microsculpture of microradial

threads and low, broad spiral cords; umbilicus wide V-shaped, diameter 0.57–0.74 mm (mean 0.67 mm), D/U 2.10–2.43 (mean 2.32). Based on 7 measured adult specimens.

Distribution and habitat. Homevale NP, MEQ; rainforest living in litter.

Remarks. *Isolderopa diamante* sp. nov. is distinguished from its congeners (excluding *I. minuta*) by having a smaller shell diameter. *Isolderopa diamante* can be separated from *I. minuta* by having a larger protoconch diameter and D/U ratio and a smaller H/D ratio. Unlike other *Isolderopa* species which have more widely ranging distributions. *Isolderopa diamante* appears to be endemic to a small area of dry rainforest in the Diamond Cliffs, MEQ. Thirty million years ago a series of eruptions covered older basalt rocks with lava, creating hard granite formations. Over time, basalt eroded away more easily leaving the Diamond Cliffs on the eastern escarpment of Mt Britton. No other species of *Isolderopa* is hitherto known from this area.

Tristanoropa gen. nov.

Type species. *Tristanoropa hughesae* sp. nov.

Etymology. From the tale of 'Tristan and Isolde' inspired by Celtic legend and the relationship to *Isolderopa* and a contraction of Charopa.

Diagnosis. Shell tiny, brown, discoidal, multi-whorled with a flat spire, whorls numerous (>4.5) and tightly coiled; sutures impressed; protoconch finely cancellate with 17–19 scalloped spiral cords, mean radial rib spacing 10 µm, protoconch length 1.50–1.625 whorls; teleoconch bladed with crowded radial ribs, microsculpture of prominent microradial threads and numerous, well-defined microspiral cords lifting over the microradial ribs; umbilicus V-shaped.

Remarks. *Tristanoropa* gen. nov. is distinguished from other MEQ genera with a finely cancellate protoconch by the combination of multi-whorled coiling pattern and flat spire. *Tristanoropa* is similar to *Shearopa* from SEQ and WT, in shell sculpture and coiling pattern but lacks the lamellate barriers of the latter. The umbilicus also differs between the two genera, being V-shaped in

Tristanoropa species and wide cup-shaped in *Shearopa* species.

***Tristanoropa hughesae* sp. nov.**

(Figs 6A, 9A, 13A, 17, Table 1)

Etymology. Named for Professor Jane Hughes from Griffith University.

Preferred common name. Hughes' Pinwheel Snail.

Materials examined. Holotype. QMMO85130, Mt Charlton, Calen-Mirani Rd, rainforest, 21°00'S, 148°42'E, litter, 129 m, coll. G. Annabell, 18.iv.1984. Diameter 2.21 mm, height 1.31 mm, H/D 0.59, D/U 4.5, number of whorls 4.375.

Paratypes. QMMO85136, 7RC, Mt Charlton, 2 miles N, Calen-Mirani Rd, rainforest, 21°01'S, 148°03'E, litter, coll. G. Annabell, 11.iv.1982.

Other Material. Calen - Mt Charlton Rd: QMMO13099, 10RC. Eungella NP: QMMO50881, 3RC; QMMO59542, 1SC; QMMO50887, 8RC; QMMO50892, 1RC; QMMO50897, 2RC; QMMO50905, 2RC; QMMO51000, 2RC. Mt Dalrymple: QMMO36095, 2SC

Diagnosis. Shell tiny, brown, mean diameter 1.66 mm, multi-whorled with a flat spire, mean shell height 0.94 mm, tightly coiled laterally compressed; protoconch finely cancellate with mean 18 scalloped spiral cords, mean radial rib spacing 10 µm, protoconch diameter 410 µm, mean 1.52 whorls; teleoconch with mean 109 crowded, radial ribs on first whorl; umbilicus V-shaped, mean D/U 2.59.

Description. Shell tiny, brown, discoidal with a flat spire, whorls 4.50–5.00 multi-whorled, sutures impressed; diameter of shell 1.39–1.89 mm (mean 1.66 mm), height 0.82–1.07 mm (mean 0.94 mm), H/D 0.48–0.62 (mean 0.57). Protoconch flat, 1.50–1.625 whorls with a diameter of 410 µm sculptured with a scalloped finely cancellate pattern consisting of fine, crisp, crowded spiral cords and widely spaced, strong radial ribs; teleoconch sculpture of bladed, very crowded radial ribs 104–112 (mean 109) on the first whorl, microsculpture of microradial threads and low, broad spiral cords; umbilicus wide V-shaped, diameter 0.57–0.74 mm (mean 0.64 mm), D/U 2.38–3.00 (mean 2.59). Based on 7 measured adult specimens.

Distribution and habitat. Eungella NP and Mt Charlton, MEQ; rainforest and vine thicket living in litter.

Remarks. *Tristanoropa hughesae* is distinguished from its congener by having a greater number of whorls, a larger protoconch diameter and more finely spaced ribs on the teleoconch. *Tristanoropa hughesae* can also be differentiated from *T. conwayensis* sp. nov. by its shorter mean protoconch length of 1.52 whorls. A close examination of the finely cancellate protoconch patterns show that of *T. hughesae* (mean 18 spiral cords) is similar to that of *T. conwayensis*, (mean 19 spiral cords) with both revealing a strongly 'rectangular' pattern.

***Tristanoropa conwayensis* sp. nov.**

(Figs 6B, 9B, 13B, 17, Table 1)

Etymology. Named for the Conway Range, MEQ, which includes the type locality of Brandy Creek SF.

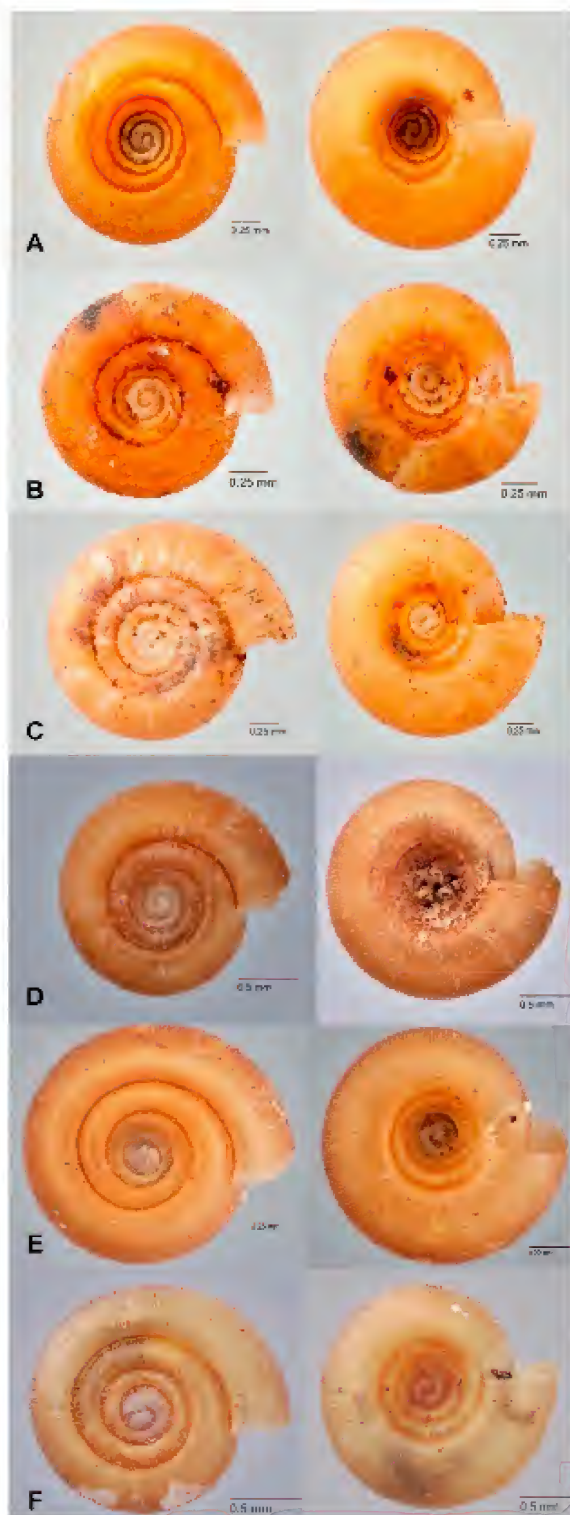
Preferred common name. Brandy Creek Pinwheel Snail.

Materials examined. Holotype. AMSC154891, Brandy Ck SF, E of Proserpine, MEQ, 20° 21'S, 148° 43'E, 120 m, cnvf, litter, coll. J. Burch, W. Ponder, 2.v.1975. Diameter 1.72 mm, height 0.98 mm, H/D 0.57, D/U 2.63, number of whorls 4.675.

Paratypes. AMSC560994, same data as holotype; QMMO85336, 3SC, Brandy Creek NP, MEQ, 20° 21'S, 148° 43'E, rainforest, litter, under logs, coll. J. Stanicic, L. Holcroft, 14.xi.2016.

Diagnosis. Shell tiny, brown, mean diameter 1.73 mm, multi-whorled with a flat spire, mean shell height 1.02 mm, tightly coiled laterally compressed; protoconch finely cancellate with mean 19 scalloped spiral cords, mean radial rib spacing 10 µm, protoconch diameter 330 µm, 1.6 whorls; teleoconch with mean 79 crowded, radial ribs on first whorl; umbilicus V-shaped, mean D/U ratio 2.62.

Description. Shell tiny, brown, discoidal with a flat spire, whorls 4.25–5.25 multi-whorled, sutures impressed; diameter of shell 1.64–1.89 mm (mean 1.73 mm), height 0.98–1.23 mm (mean 1.02 mm); H/D 0.52–0.65 (mean 0.59). Protoconch flat, 1.50–1.625 (mean 1.53) whorls with a diameter of 330 µm sculptured with a scalloped finely cancellate pattern consisting



of fine, crisp, crowded spiral cords and widely spaced, weak radial ribs; teleoconch sculpture of bladed, crowded radial ribs 70–96 on first whorl, microsculpture of microradial threads and low, broad spiral cords; umbilicus wide V-shaped, diameter 0.57–0.74 mm (mean 0.67 mm). D/U 2.22–3.29 (mean 2.62). Based on 8 measured adult specimens.

Distribution and habitat. Brandy Creek SF, Conway Range, MEQ; rainforest living in litter.

Remarks. *Tristanoropa conwayensis* sp. nov. is distinguished from *T. hughesae* sp. nov. by having a smaller protoconch diameter, a larger H/D ratio and shell height and less ribs on the teleoconch. *Tristanoropa conwayensis* has a greater number of spiral cords on the protoconch (mean 19) than *T. hughesae* (mean 18) spiral cords. *Tristanoropa conwayensis* appears to be endemic to the rainforests of Brandy Creek NP, MEQ.

DISCUSSION

The charapid land snails of MEQ include a number of tiny species that have finely cancellate protoconchs (Holcroft 2018a). The generic assignment of these species that have broadly similar finely cancellate protoconch sculpture relies heavily on conchological features such as shell microsculpture (protoconch and teleoconch) and general shell features (spire protrusion, umbilical width, coiling pattern). Emphasis on shell morphology has been necessitated by the lack of suitable material for molecular analyses and anatomical dissection.

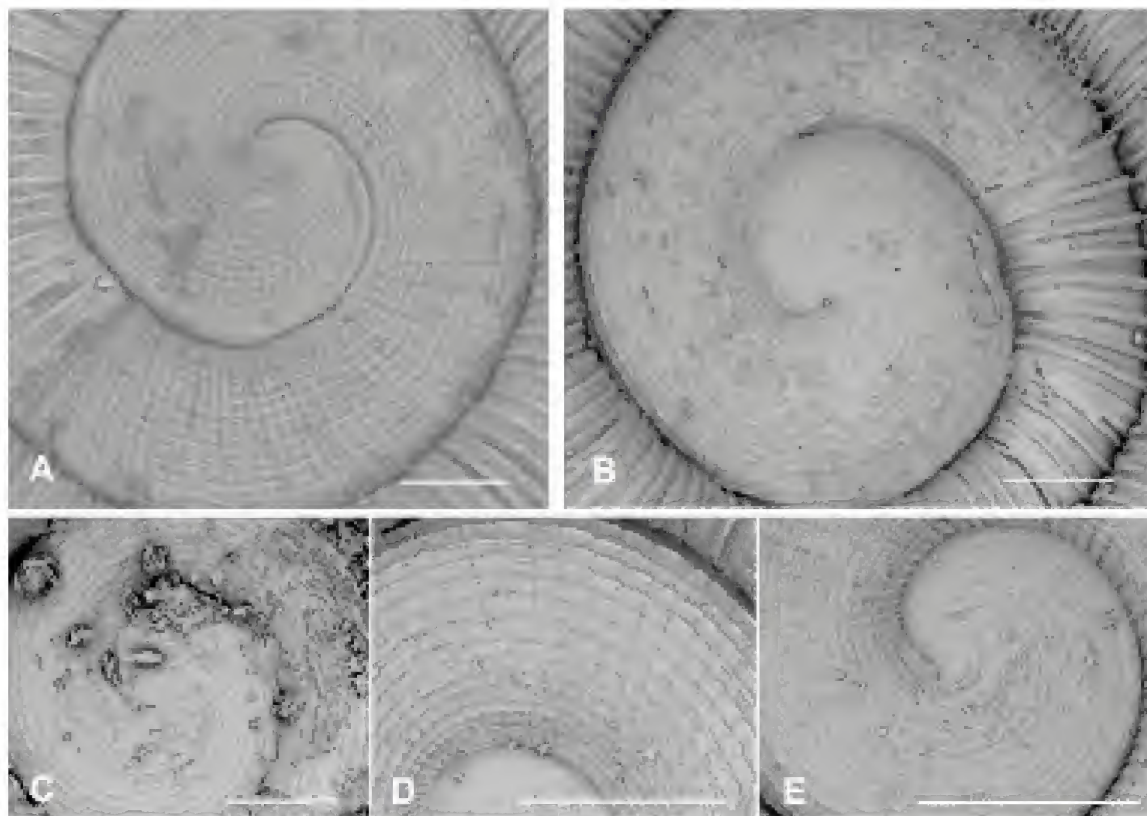
The shared finely cancellate protoconch sculpture of these genera is visible by optical microscopy but the differences between the

FIG. 12. Dorsal and ventral views of holotypes of *Isolderopa* species. A, *I. iangallowayi*, QMMO13102, SW of Calen Charlton, MEQ; B, *I. minuta*, QMMO13445, Eungella NP, MEQ; C, *I. deliqua*, QMMO13101, SW Calen, MEQ; D, *I. teemburra* sp. nov., QMMO35809, Endeavour Ck, MEQ; E, *I. whitsunday* sp. nov., QMMO11902, Cape Hillsborough, MEQ; F, *I. diamante* sp. nov., QMMO86546, Diamond Cliffs, MEQ. Images: Geoff Thompson, QM.



FIG. 13. Dorsal and ventral views of the holotypes of *Tristanoropa* gen. nov. species. **A**, *T. hughesae* sp. nov., QMMO85130, Mt Charlton, MEQ; **B**, *T. conwayensis* sp. nov., AMSC154891, Brandy Creek, MEQ. Images: Geoff Thompson, QM.

FIG. 14. Finely cancellate protoconch sculpture of SEQ and NEQ charopids. **A**, Webbed variant of *Shearopa offordae*, QMMO85145, Yeppoon, SEQ; **B**, Scalloped variant of *Shearopa magnetica*, QMMO78975, Magnetic Island, NEQ; **C**, Spiral pattern with finely cancellate pattern emerging after 1 whorl of *Excaliburopa leroii* Stanisic, 2010, QMMO79893, Undara Crater, NEQ; **D**, Webbed variant of Charopid WT41, QMMO73854, Bakers Blue Mt., FNQ; **E**, Webbed variant of Charopid MQ53 from Byfield NP, MEQ. Scale bars = 100 μ m.



genera are subtle and discernible only by SEM. However, shell coiling pattern and spire protrusion provide two general shell characters by which the genera may be distinguished.

The nautiloid coiling pattern of *Pereduropa* and *Isolderopa* is similar but the genera differ in that *Pereduropa* species feature a flat to slightly raised spire while those of *Isolderopa* have a biconcave shell and depressed spire. *Tristanoropa* differs from both by having a tight multi-whorled shell and a flat spire. *Isolderopa* is the only one of the three genera that includes species with apertural barriers, although they are absent in some *Isolderopa* species.

From the evidence available, all three genera appear endemic to MEQ. Investigation of species in the neighbouring regions of SEQ and NEQ considered other taxa with a finely cancellate protoconch sculpture: *Shearopa offordae* Stanislac, 2010 from Yeppoon, SEQ, *S. magnetica* Stanislac, 2010 from Magnetic Island, NEQ, *Excaliburopa leroii* Stanislac, 2010 from Undara Crater, NEQ, Charopid WT41 from Bakers Blue Mt., NEQ and Charopid MQ53 from Byfield NP, SEQ. Each of these species demonstrated significant variation in the finely cancellate protoconch pattern from that found in MEQ species (Fig. 14). The webbed variant displayed by *S. offordae*, Charopid WT41 from Bakers Blue Mt, WT and Charopid MQ53 from the Byfield area, SEQ, separate these species from any in MEQ. The strongly spiral protoconch sculpture in the first protoconch whorl of *E. leroii* is also a factor distinguishing this species from all MEQ species. *Shearopa magnetica* has a similar protoconch sculpture to the MEQ species but the protoconch has more spiral cords (>20) than any MEQ species. It can also be distinguished from all MEQ species by having apertural barriers with numerous lamellae, three to four parietal outside the apertural edges and seven to eight internal palatals (Stanislac *et al.* 2010) unlike any *Isolderopa* species.

At the species level, protoconch diameter is a characteristic that appears to be uniform within each species (Appendix), and thus may be useful for species differentiation within charopids. Investigation of a wider range of

species will be needed to confirm that this measurement is as instructive as it appears in differentiating the species in the three genera treated here.

The distribution of the 12 species of MEQ charopids with a finely cancellate protoconch documented in this study centres around the moist rainforests of the Eungella NP and surrounds and the drier araucarian rainforests of the coastal uplands of the Conway Range and Mt Dryander NPs. Species are also found in similar dry rainforests on many of the Whitsunday Islands. Unlike the larger *Gyrocochlea*-grade charopid species of MEQ (Holcroft 2018b), species of *Pereduropa* and *Isolderopa* are known from Cape Hillsborough, MEQ.

Of note, the type species of *Pereduropa* (*P. cursacosta*) has only been found south of Proserpine in the Clarke-Connors Range sub-region as well as in two coastal locations (Fig. 15). *Pereduropa delicata* is known from north of Proserpine and also in the Conway and Mt Dryander NPs. *Pereduropa hamiltoniana* is endemic to the Whitsunday islands and *P. burwelli* to the Eungella plateau.

Isolderopa shares a comparable distribution to that of *Pereduropa* (Fig. 16). *Isolderopa iangallowayi*, *I. minuta* and *I. deliqua* are endemic to the Clarke-Connors Range. *Isolderopa teemburra* is endemic to the Crediton SF in the environs of Teemburra Creek and its tributaries, viz. Endeavour Creek and Cherry Tree Creek. *Isolderopa diamante* is endemic to the Diamond Cliffs, Homevale NP and *I. whitsunday* to the Whitsunday region.

Tristanoropa has two species with very localised distributions, *T. conwayensis* endemic to the Conway Range and *T. hughesae* endemic to Eungella NP (Fig. 17). No species of *Tristanoropa* have been described from any of the Whitsunday islands. However, several undescribed specimens in the QM collection from South Molle Island and Gloucester Island may also be members of this genus. Further undescribed single specimens from St Helen's Beach and another from Hazelwood Gorge near the Eungella Dam may also be new *Tristanoropa* species.



FIG. 15. Map of localities *Pereduropa* species based on material examined. Species are identified by the following symbols: ■ *Pereduropa cursacosta*; ▲ *Pereduropa delicata*; ● *Pereduropa hamiltoniana*; ★ *Pereduropa burwelli* sp. nov.



FIG. 16. Map of localities *Isolderopa* species based on material examined. Species are identified by the following symbols: ■ *Isolderopa iangallowayi*; ▲ *Isolderopa minuta*; ● *Isolderopa deliqua*; ▼ *Isolderopa teemburra* sp. nov.; ★ *Isolderopa whitsunday* sp. nov.; ◆ *Isolderopa diamante* sp. nov.

While *I. iangallowayi*, *I. minuta* and *I. deliqua* appear to live in close proximity on the Eungella plateau, congeneric sympatry in charopids is highly unusual (Shea *et al.* 2012). The aforementioned three species occur in the higher altitude rainforests of Eungella NP. It may well be that these tiny snails live in tiny pockets of this extensive rainforest as no two have been found in exactly the same location (microsympatrically). However, further collecting particularly of live material allowing for DNA analysis will be necessary to understand this complex scenario.

The distribution of several species across the Clarke-Connors Range and Whitsunday

subregions alludes to an historically widespread distribution of these tiny charopids prior to the aridification of the continent and contraction of rainforest in the Miocene (Kemp 1981). Ancient distributions would have been fractured with possible subsequent local species extinctions resulting in the current disjunct pattern for *Isolderopa minuta*. The land clearing of the Mackay-Proserpine lowlands in recent history may have contributed to loss of species in the areas between these two major areas of rainforest.

This study has a major emphasis on shell morphology. It is recommended that future collecting focus on animal tissue suitable for



FIG. 17. Map of localities *Tristanoropa* gen. nov. species based on material examined. Species are identified by the following symbols: ■ *Tristanoropa hughesae* sp. nov.; ▲ *Tristanoropa conwayensis* sp. nov.

molecular and anatomical analyses so that a more comprehensive systematics, combining DNA sequence data and morphological information, can enhance our understanding of these tiny MEQ charopids and thus provide a more integrative taxonomy.

ACKNOWLEDGMENTS

I would like to thank Dr John Staniscic from the Queensland Museum whose insight and expertise greatly assisted this research. I would also like to express my deep gratitude to my supervisors Professor Jane Hughes (Griffith University) and Dr Chris Burwell (Griffith University and Queensland Museum) for their support, continual encouragement and comprehensive feedback. I am also immensely grateful to Geoff Thompson from

the Digital Imaging Unit at the Queensland Museum for the high quality photography of these tiny snails. I also thank the reviewers, Dr John Healy and Dr Jonathon Parkyn for their insights and constructive feedback.

LITERATURE CITED

- Bureau of Meteorology. 2017. Climate statistics for Australian locations. Available online at <http://www.bom.gov.au> (Accessed on 4 January 2018).
- Holcroft, L. 2018a. Protoconch sculpture as a taxonomic tool in Australian charopid systematics (Gastropoda: Eupulmonata: Charopidae). *Molluscan Research*, <https://doi.org/10.1080/13235818.2017.1409069>.
- Holcroft, L. 2018b. A revision of *Gyrocochlea*-grade Charopidae from mid-eastern Queensland and redescription and generic reassignment of three *Gyrocochlea*-grade species (Eupulmonata: Charopidae). *Memoirs of the Queensland Museum - Nature* **61**. <https://doi.org/10.17082/j.2204-1478.61.2018.2017-14>.
- Hyman, I.T. & Staniscic, J. 2005. New charopid landsnails, chiefly from limestone outcrops in eastern New South Wales (Eupulmonata: Charopidae). *Memoirs of the Queensland Museum* **50**: 219-302.
- Kemp, E.M. 1981 Tertiary paleogeography and the evolution of Australian climate. In: A. Keast (ed.), *Ecological Biogeography of Australia*, pp. 32-49. W. Junk Publishers: The Hague, Netherlands.
- Shea, M., Colgan, D. & Staniscic, J. 2012. Systematics of the landsnail genus *Gyrocochlea* and relatives (Mollusca: Charopidae). *Zootaxa* **3585**: 1-109.
- Solem, A. 1983. Endodontoid land snails from Pacific Islands (Mollusca: Pulmonata: Sigmurethra). Part II. Families Punctidae and Charopidae, Zoogeography. (Field Museum: Chicago).
- Staniscic, J. 1990. Systematics and biogeography of eastern Australian Charopidae (Mollusca: Pulmonata) from sub-tropical rainforests. *Memoirs of the Queensland Museum* **30**: 1-241.
- Staniscic, J. 1998. Family Charopidae. Pp. 1097-1099 In: Beesley, P. L., Ross, G. J. B. & Wells, A. (eds) *Mollusca: The Southern Synthesis. Fauna of Australia*. Vol. 5. CSIRO Publishing: Melbourne, Part B viii, 565-1234pp.
- Staniscic, J. 2016. Two new species of Pinwheel Snail from Queensland and a redescription and generic

reassignment of *Gyrocochlea myora* Stanisic, 2010 (Gastropod: Eupulmonata: Charopidae). *Memoirs of the Queensland Museum–Nature* 60: 1–12 <https://doi.org/10.17082/j.2204-1478.60.2016.2016-07>.

Stanisic, J., Shea, M., Potter, D. & Griffiths, O. 2010. *Australian Land Snails Volume 1: A Field Guide to Eastern Australian Species*. (Bioculture Press: Mauritius) 596pp.

APPENDIX. Species measurements for adult specimens used in this study. Diameter (D), Height (H), Umbilical width (U), Aperture Height (AH), Aperture width (AW), Protoconch diameter (PD) in mm. Protoconch length is measured in the number of whorls. H/D and D/U are ratios. The number of ribs on the first whorls of the teleoconch (T1) and the number of ribs in the third quadrant of the body whorl (WWB) are counts.

Species	Reg #	D	H	U	AH	AW	PD	WWB	T1	H/D	D/U	# Whorls	PL
<i>Pereduropa cursacosta</i>	QMMO78972	2.30	1.23	0.82	0.98	0.82	0.41	38	56	0.54	2.80	4.125	1.5
	QMMO78972	2.13	1.31	0.82	0.82	0.74	0.41	30	44	0.62	2.60	4.125	1.5
	QMMO78972	2.46	1.31	0.74	1.07	0.90	0.41	37	48	0.53	3.33	4.500	1.5
	QMMO19993	2.54	1.48	0.82	0.90	0.98	0.41	27	48	0.58	3.10	4.125	1.5
	QMMO11901	2.30	1.39	0.74	0.98	0.82	0.41	23	47	0.61	3.11	4.125	1.5
	QMMO11901	2.21	1.23	0.82	0.90	0.82	0.41	22	49	0.56	2.70	4.000	1.5
	QMMO85127	2.46	1.31	0.90	0.98	0.90	0.41	28	60	0.53	2.73	4.125	1.5
	QMMO85133	2.46	1.48	0.90	0.90	0.90	0.41	26	45	0.60	2.73	4.250	1.5
	MEAN	2.36	1.34	0.82	0.94	0.86	0.41	29	50	0.57	2.89	4.17	1.50
<i>Pereduropa delicata</i>	QMMO35547	1.72	0.98	0.74	0.82	0.74	0.41	35	82	0.57	2.33	4.000	1.5
	QMMO78971	2.05	0.98	0.90	0.82	0.66	0.41	31	78	0.48	2.27	4.250	1.5
	QMMO78971	1.80	1.07	0.74	0.82	0.74	0.41	32	68	0.59	2.44	4.250	1.5
	AMSC154896	2.05	1.15	0.57	0.98	0.82	0.41	25	67	0.56	3.57	4.375	1.625
	AMSC154896	2.21	1.23	0.74	0.90	0.82	0.41	29	79	0.56	3.00	4.875	1.5
	AMSC154896	2.13	1.23	0.82	0.90	0.82	0.41	32	76	0.58	2.60	4.500	1.5
	AMSC154896	2.13	1.15	0.74	0.74	0.66	0.41	25	62	0.54	2.89	4.500	1.5
	MEAN	2.01	1.11	0.75	0.85	0.75	0.41	30	73	0.55	2.73	4.39	1.52
	QMMO78970	1.80	1.07	0.57	0.90	0.66	0.41	15	44	0.59	3.14	4.250	
<i>Pereduropa hamiltoniana</i>	QMMO78970	1.89	1.15	0.66	0.74	0.57	0.41	17	44	0.61	2.88	4.375	1.5
	QMMO78970	1.89	1.07	0.66	0.82	0.57	0.41	16	42	0.57	2.88	4.375	1.625
	QMMO78970	1.89	0.98	0.66	0.82	0.66	0.41	17	45	0.52	2.88	4.250	
	QMMO60585	1.89	1.15	0.57	0.90	0.66	0.41	19	45	0.61	3.29	4.250	1.625
	QMMO86089	2.05	1.07	0.74	0.82	0.82	0.41	18	42	0.52	2.78	4.375	1.5
	MEAN	1.90	1.08	0.64	0.83	0.66	0.41	17	44	0.57	2.97	4.31	1.56
	QMMO6372	2.21	1.31	0.49	0.98	0.82	0.49	35	117	0.59	4.50	4.375	1.875
	QMMO85105	2.38	1.48	0.66	1.07	0.82	0.49	40	107	0.62	3.63	4.500	1.75
	QMMO85103	2.38	1.48	0.57	1.07	0.98	0.49	42	99	0.62	4.14	4.250	1.5
<i>Pereduropa burwelli</i>	QMMO6369	2.05	1.23	0.57	0.90	0.82	0.49	26	78	0.60	3.57	4.125	1.625
	QMMO6369	2.13	1.15	0.74	0.90	0.74	0.49	37	99	0.54	2.89	4.250	1.75
	QMMO6369	2.13	1.15	0.66	0.90	0.74	0.49	34	82	0.54	3.25	4.250	1.75
	AMSC154908	2.54	1.48	0.66	1.15	0.98	0.49	45	109	0.58	3.88	4.500	1.625
	AMSC154899	2.30	1.15	0.57	0.98	0.90	0.49	38	116	0.50	4.00	4.250	1.75
	QMMO13075	2.13	1.15	0.74	0.98	0.82	0.49	34	75	0.54	2.89	4.000	1.625
	QMMO6355	2.21	1.31	0.66	0.98	0.90	0.49	39	112	0.59	3.38	4.25	1.625
	QMMO11759	2.46	1.48	0.74	1.15	0.82	0.49	46	75	0.60	3.33	4.375	1.625
	QMMO6374	2.05	0.98	0.66	0.90	0.74	0.49	36	102	0.48	3.13	4.125	1.75
	QMMO6374	2.05	1.15	0.66	0.90	0.74	0.49	39	97	0.56	3.13	4.125	1.75
	QMMO42392	2.21	1.23	0.74	1.07	0.82	0.49	37	72	0.56	3.00	4.125	1.625
	QMMO6365	2.13	1.15	0.66	0.90	0.74	0.49	32	98	0.54	3.25	4.250	1.625
	MEAN	2.21	1.24	0.66	0.98	0.83	0.49	37	93	0.56	3.37	4.22	1.66

Appendix continued ...

Species	Reg #	D	H	U	AH	AW	PD	WWB	T1	H/D	D/U	# Whorls	PL
<i>Isolderopa iangallewayi</i>	AMSC140446	1.89	1.15	0.66	0.98	0.74	0.33	42	94	0.61	2.88	5.000	1.75
	AMSC140446	1.80	1.15	0.74	1.07	0.74	0.33	40	88	0.64	2.44	5.000	1.5
	AMSC140446	2.13	1.31	0.74	1.07	0.74	0.33	47	106	0.62	2.89	5.125	1.675
	QMMO85131	1.97	1.15	0.66	0.98	0.82	0.33	56	107	0.58	3.00	5.250	1.5
	QMMO50891	1.89	1.23	0.74	1.07	0.74	0.33	40	93	0.65	2.56	5.375	1.75
	QMMO78962	1.80	1.07	0.74	0.90	0.66	0.33	50	90	0.59	2.44	5.250	1.75
	QMMO78962	1.89	1.15	0.74	0.98	0.74	0.33	55	103	0.61	2.56	5.250	1.75
	QMMO78962	1.80	1.07	0.74	0.98	0.66	0.33	72	120	0.59	2.44	5.000	1.675
	QMMO50880	1.72	1.15	0.66	0.98	0.66	0.33	45	97	0.67	2.63	5.000	1.675
	QMMO50880	1.56	1.15	0.66	1.07	0.66	0.33	42	104	0.74	2.38	4.875	1.75
	QMMO50885	1.97	1.23	0.66	1.15	0.74	0.33	51	120	0.63	3.00	5.250	1.75
	QMMO50885	1.89	1.15	0.74	1.07	0.66	0.33	52	109	0.61	2.56	5.250	1.675
	QMMO86088	1.89	1.15	0.66	0.98	0.66	0.33	48	119	0.61	2.88	5.250	1.75
	QMMO86088	1.89	1.15	0.66	0.98	0.66	0.33	44	102	0.61	2.88	5.250	1.75
	MEAN	1.86	1.16	0.70	1.02	0.70	0.33	49	104	0.62	2.68	5.15	1.69
<i>Isolderopa minuta</i>	QMMO78980	1.39	0.82	0.66	0.74	0.41	0.25	56	129	0.59	2.13	4.500	1.675
	QMMO78980	1.31	0.82	0.66	0.74	0.66	0.25	56	116	0.63	2.00	4.500	1.675
	QMMO50886	1.31	0.74	0.66	0.66	0.57	0.25	61	120	0.56	2.00	4.375	1.5
	QMMO50886	1.48	0.82	0.66	0.74	0.66	0.25	63	132	0.56	2.25	4.250	1.675
	QMMO85100	1.56	0.90	0.74	0.74	0.41	0.25	63	112	0.58	2.11	4.675	1.5
	QMMO85077	1.31	0.82	0.57	0.74	0.49	0.25	43	122	0.63	2.29	4.250	1.675
	QMMO85087	1.39	0.90	0.66	0.66	0.41	0.25	60	127	0.65	2.13	4.500	1.75
	QMMO85106	1.23	0.66	0.57	0.57	0.41	0.25	65	124	0.53	2.14	4.000	1.75
	QMMO85085	1.48	0.82	0.66	0.66	0.41	0.25	67	132	0.56	2.25	4.375	1.625
	QMMO85137	1.64	0.90	0.66	0.74	0.57	0.25	58	124	0.55	2.50	4.750	1.75
	MEAN	1.41	0.82	0.65	0.70	0.50	0.25	59	124	0.58	2.18	4.42	1.66
<i>Isolderopa deliqua</i>	QMMO78960	1.97	1.07	0.82	0.82	0.74	0.33	40	110	0.54	2.40	4.750	1.625
	QMMO78960	1.72	0.98	0.82	0.82	0.66	0.33	41	115	0.57	2.10	4.125	1.625
	QMMO6354	2.05	1.23	0.74	0.90	0.66	0.33	37	90	0.60	2.78	4.250	1.625
	QMMO6354	1.80	1.23	0.74	0.90	0.57	0.33	36	111	0.68	2.44	4.250	1.625
	QMMO6354	1.64	0.90	0.82	0.90	0.57	0.33	29	99	0.55	2.00	4.000	1.625
	QMMO9725	1.97	1.07	0.82	0.90	0.66	0.33	45	102	0.54	2.40	4.500	1.625
	QMMO9725	2.13	1.15	0.82	1.07	0.66	0.33	43	97	0.54	2.60	4.500	1.625
	QMMO9725	1.97	1.15	0.82	0.90	0.66	0.33	39	87	0.58	2.40	4.500	1.625
	QMMO13452	1.97	1.15	0.82	0.90	0.57	0.33	36	87	0.58	2.40	4.375	1.625
	QMMO13452	2.21	1.15	0.82	0.98	0.66	0.33	36	101	0.52	2.70	4.750	1.5
	QMMO85132	2.05	1.07	0.82	0.90	0.74	0.33	37	102	0.52	2.50	4.500	1.75
	MEAN	1.95	1.10	0.80	0.91	0.65	0.33	38	100	0.57	2.43	4.41	1.625
<i>Isolderopa teemburra</i>	QMMO35809	2.05	1.23	0.90	0.90	0.66	0.33	42	122	0.60	2.27	4.375	1.75
	QMMO86547	1.97	1.07	0.98	0.90	0.66	0.33	46	110	0.54	2.00	4.500	1.625
	QMMO86547	1.89	1.07	0.90	0.82	0.74	0.33	48	125	0.57	2.09	4.375	1.75
	MEAN	1.97	1.12	0.93	0.87	0.68	0.33	45	119	0.57	2.12	4.42	1.71
<i>Isolderopa whitsunday</i>	QMMO6348	1.64	0.82	0.66	0.74	0.49	0.33	55	129	0.50	2.50	4.250	1.5
	QMMO6348	1.80	0.90	0.66	0.74	0.49	0.33	57	121	0.50	2.75	4.500	1.5
	QMMO6348	1.72	0.82	0.66	0.74	0.41	0.33	55	129	0.48	2.63	4.500	1.5
	QMMO13089	1.56	0.90	0.66	0.74	0.49	0.33	51	117	0.58	2.38	4.625	1.5
	QMMO86548	1.48	0.82	0.66	0.74	0.49	0.33	48	114	0.56	2.25	4.375	1.625
	QMMO86548	1.56	0.82	0.66	0.74	0.41	0.33	50	117	0.53	2.38	4.625	1.625
	QMMO11902	1.64	0.90	0.74	0.74	0.41	0.33	51	120	0.53	2.38	4.125	1.5
	AMSC154890	1.64	0.90	0.74	0.74	0.41	0.33	59	116	0.55	2.22	4.625	1.5

A revision of Charopidae with a finely cancellate protoconch sculpture

Appendix continued ...

Species	Reg #	D	H	U	AH	AW	PD	WWB	T1	H/D	D/U	# Whorls	PL
<i>Isolderopa whitsunday</i> cont...	QMMO74081	1.48	0.82	0.66	0.74	0.41	0.33	51	126	0.55	2.22	4.250	1.5
	QMMO65835	1.56	0.82	0.66	0.74	0.41	0.33	51	122	0.53	2.38	4.375	1.625
	QMMO60586	1.56	0.90	0.66	0.74	0.49	0.33	50	112	0.58	2.38	5.000	1.5
	QMMO85128	2.05	0.90	0.90	0.74	0.49	0.33	52	108	0.44	2.27	4.125	1.5
	QMMO85128	1.89	0.90	0.90	0.74	0.49	0.33	63	108	0.48	2.09	4.875	1.5
	QMMO85128	1.80	0.90	0.74	0.74	0.49	0.33	53	111	0.50	2.44	4.875	1.5
	QMMO68647	1.64	0.82	0.66	0.74	0.49	0.33	54	130	0.50	2.50	4.500	1.625
	QMMO85138	1.64	0.82	0.66	0.74	0.49	0.33	51	117	0.50	2.50	4.625	1.625
	QMMO85138	1.56	0.82	0.66	0.74	0.41	0.33	50	111	0.53	2.38	4.375	1.625
	QMMO85138	1.72	0.82	0.66	0.74	0.49	0.33	51	112	0.48	2.63	4.500	1.5
	MEAN	1.66	0.86	0.70	0.74	0.46	0.33	53	118	0.52	2.40	4.51	1.54
<i>Isolderopa diamante</i>	QMMO77078	1.39	0.90	0.57	0.82	0.49	0.33	36	102	0.65	2.43	3.875	1.75
	QMMO77078	1.56	0.90	0.66	0.82	0.66	0.33	37	107	0.58	2.38	4.000	1.75
	QMMO77078	1.56	0.90	0.66	0.82	0.66	0.33	37	107	0.58	2.38	4.000	1.75
	QMMO77078	1.56	0.90	0.66	0.82	0.66	0.33	37	107	0.58	2.38	4.000	1.75
	QMMO86071	1.56	0.90	0.74	0.82	0.49	0.33	39	104	0.58	2.11	4.000	1.625
	QMMO77078	1.72	1.15	0.74	0.90	0.57	0.33	41	114	0.67	2.33	4.250	1.625
	QMMO77078	1.48	0.82	0.66	0.74	0.49	0.33	45	117	0.56	2.25	3.750	1.5
	MEAN	1.55	0.93	0.67	0.82	0.57	0.33	39	108	0.60	2.32	3.98	1.68
<i>Tristanoropa</i> <i>conwayensis</i>	AMSC154891	1.64	0.98	0.66	0.74	0.57	0.33	33	75	0.60	2.50	4.500	1.625
	AMSC154891	1.89	1.07	0.74	0.74	0.66	0.33	37	73	0.57	2.56	4.875	1.5
	AMSC154891	1.72	0.98	0.66	0.74	0.57	0.33	33	70	0.57	2.63	4.675	1.5
	AMSC154891	1.64	1.07	0.66	0.74	0.66	0.33	34	86	0.65	2.50	4.500	1.5
	AMSC154891	1.56	0.90	0.66	0.74	0.49	0.33	33	75	0.58	2.38	4.375	1.5
	AMSC154891	1.89	0.98	0.57	0.82	0.74	0.33	30	69	0.52	3.29	4.250	1.5
	QMMO85336	1.89	1.23	0.66	0.74	0.66	0.33	39	90	0.65	2.88	5.250	1.625
	QMMO85336	1.64	0.98	0.74	0.57	0.66	0.33	40	96	0.60	2.22	4.500	1.5
	MEAN	1.73	1.02	0.67	0.73	0.63	0.33	35	79	0.59	2.62	4.62	1.53
<i>Tristanoropa hughesae</i>	QMMO13099	1.72	0.82	0.66	0.74	0.57	0.41	62	111	0.48	2.63	4.625	1.5
	QMMO13099	1.72	1.07	0.57	0.90	0.66	0.41	55	112	0.62	3.00	4.500	1.625
	QMMO85136	1.89	0.98	0.74	0.90	0.66	0.41	59	104	0.52	2.56	4.750	1.5
	QMMO50905	1.64	0.98	0.66	0.74	0.66	0.41	50	115	0.60	2.50	4.725	1.5
	QMMO50887	1.72	0.98	0.66	0.74	0.66	0.41	60	112	0.57	2.63	5.000	1.5
	QMMO50892	1.56	0.90	0.66	0.66	0.66	0.41	52	104	0.58	2.38	4.875	1.5
	QMMO50881	1.39	0.82	0.57	0.66	0.57	0.41	49	105	0.59	2.43	4.675	1.5
	MEAN	1.66	0.94	0.64	0.76	0.63	0.41	55	109	0.57	2.59	4.74	1.52

Trypanorhynch cestodes (Platyhelminthes) parasitic in elasmobranchs and crustaceans in Moreton Bay, Queensland

Ian BEVERIDGE¹ & Bjoern C. SCHAEFFNER²

¹Faculty of Veterinary and Agricultural Science, University of Melbourne, Veterinary Clinical Centre, Werribee, Victoria 3030, Australia. Email: ibeve@unimelb.edu.au.

²Institute of Parasitology, Biology Centre, Czech Academy of Sciences, České Budějovice, Czech Republic

Citation: Beveridge, I. & Schaeffner, B.C. 2018. Trypanorhynch cestodes (Platyhelminthes) parasitic in elasmobranchs and crustaceans in Moreton Bay, Queensland. *Memoirs of the Queensland Museum – Nature* 61:109–142. Brisbane. ISSN 2204-1478 (Online). ISSN 0079-8835 (Print). Accepted: 5 June 2018. First published online: 22 November 2018.

<https://doi.org/10.17082/j.2204-1478.61.2018.2017-13>

LSID urn:lsid:zoobank.org:pub:AFF9A603-D9F2-4BF9-BB2A-8F9443D786E8

ABSTRACT

Examination of 64 elasmobranchs comprising 13 species from Moreton Bay yielded 13 identifiable species of cestodes of the order Trypanorhyncha Diesling, 1863. Two new species, *Dollfusiella armata* sp. nov. from *Maculabatis toshi* (Whitley, 1939) and *M. cf. astra* Last, Manjaji-Matsumoto and Pogonoski, 2008, and *Dollfusiella pilosa* sp. nov. from *Aetobatus ocellatus* (Kuhl, 1823) are described. *Prochristianella odonoghuei* Beveridge, 1990 becomes a junior synonym of *Prochristianella butlerae* Beveridge, 1990 based on identical strobilar and tentacular morphologies. *Prochristianella omunae* Beveridge and Justine, 2010 is reported from Australia for the first time, where it was recovered from the type host *Neotrygon trigonoides* (Castelnau, 1873). Additional new host records are included as well as extensions of known geographical distributions to now include south-eastern Queensland. Metacestodes were recovered from the digestive glands of yabbies, *Trypaea australis* (Dana, 1852), representing an undescribed species of *Dollfusiella*. Adults of this species were found in the spiral valves of *N. trigonoides* and *Ae. ocellatus*. Six species of metacestodes of trypanorhynch cestodes were recovered from the digestive glands of pistol shrimps, *Alpheus* spp. (*A. richardsoni* Yaldwyn, 1971 and *A. papillosus* Banner & Banner, 1982). Of these, three were identified as *Parachristianella monomegacantha* Kruse, 1959, *Prochristianella aciculata* Beveridge and Justine, 2010 and *Zygorhynchus robertsoni* Beveridge and Campbell, 1988, the adults of all three species being originally reported from batoids. Two undescribed species of *Dollfusiella* and undescribed species of *Parachristianella* and *Zygorhynchus* were also recovered from alpheid shrimps; definitive hosts were identified for each species, but the material available was insufficient to allow formal descriptions.

□ Cestoda, Trypanorhyncha, elasmobranchs, Callianassidae, Alpheidae, life cycles, new species.

Although the trypanorhynch cestode fauna of the Australian region is better known than in many other regions of the world (Beveridge *et al.* 2017b), much of the collecting upon which current reports are based has been opportunistic. The only defined region of the continent which has been relatively intensively studied is that of the South Australian Gulfs, with the elasmobranch species examined

summarised in Beveridge (1987). However, the results from this region are contained in various publications (e.g. Beveridge 1990; Beveridge & Campbell 1987, 1988a, 1996; Beveridge & Sakanari 1987; Campbell & Beveridge 1996; Palm & Beveridge 2002) with no current synthesis of the data available from these studies. Studies on the trypanorhynch fauna of Moreton Bay have been extremely

limited to date. Beveridge (1990) reported a number of species of eutetrarhynchids from batoids in Moreton Bay, while Beveridge and Campbell (1988a) described *Shirleyrhynchus butlerae* Beveridge and Campbell, 1988 from *Hemitrygon fluviorum* (Ogilby, 1908) and recorded *Callitetrarhynchus gracilis* (Rudolphi, 1819) from the same host species (Beveridge & Campbell 1996). Palm and Beveridge (2002) also reported tentaculairiid trypanorhynchs from elasmobranchs and teleosts both within Moreton Bay and from the oceanic coast of North Stradbroke Island. However, there has been no systematic collecting of trypanorhynch cestodes in this region to date.

The current report is part of an examination of the trypanorhynch fauna of Moreton Bay, Queensland. In an earlier publication, the larval trypanorhynch species in teleost fishes were reported (Beveridge *et al.* 2017a). In this paper, we report the adult species of trypanorhynchs encountered in elasmobranchs from Moreton Bay together with limited observations on intermediate stages present in crustaceans.

MATERIALS AND METHODS

Elasmobranchs, mainly batoid rays, were collected from a commercial fishery in Moreton Bay in November 2011, and January and June 2016. Photographs and/or tissue samples were collected from each fish to confirm identifications if necessary. Host specimens were identified primarily using the keys and descriptions in Last and Stephens (2009). In the case of any elasmobranchs whose identity was uncertain, entire specimens were deposited in the Queensland Museum (QM). Elasmobranch host nomenclature follows Last *et al.* (2016). In instances where host names have changed since the original publication, the original name is also cited in the text. Authorities for elasmobranch species listed in Table 1 are not repeated in the text. Collection localities within Moreton Bay are shown in Fig. 1. To avoid repetition, localities mentioned in the text are assumed to be within Moreton Bay.

Spiral valves were opened along the dorsal midline. Representative cestodes visible were

removed and placed on microscope slides in saline. A cover slip was placed over them and pressure was applied to the coverslip with fine forceps to force the eversion of tentacles. The specimens were flooded with 70% ethanol while maintaining pressure to keep the tentacles everted. Once fixed, the cestodes were stored in ethanol. The remaining spiral valve and its contents were flooded with hot saline, followed immediately with either 70% ethanol or 10% formalin. Spiral valves fixed in formalin were subsequently transferred to 70% ethanol for storage. Cestodes were removed from spiral valves and stored in 70% ethanol. Some scoleces with everted tentacles were mounted in Hoyer's medium. Entire cestodes were stained in Celestine Blue, destained in 70% acid alcohol, dehydrated in an ethanol series, cleared in methyl salicylate and mounted in Canada balsam.

Specimens selected for scanning electron microscopy were dehydrated in ethanol, transferred to hexamethyldisilazane and allowed to dry. They were mounted on stubs with carbon tape, coated with gold and examined using a FEI Nova NanoSEM 450 FEG field emission gun scanning electron microscope using an accelerating voltage of 3–10 Kv. Microthrix terminology follows Chervy (2009).

Crustaceans (*Trypaea australiensis* Dana, 1852, *Alpheus richardsoni* Yaldwyn, 1971 and *Al. papillosus* Banner & Banner, 1982) were collected at low tide on mud flats at Wynnum (November 2011) and Dunwich (May 2010, January and June 2016) in areas where batoids feed at high tide. Localities are shown in Fig. 1. Each crustacean was dissected individually, any metacestodes present in the digestive glands were placed on a microscope slide in saline, pressure was applied to a coverslip to evert tentacles and then the slide was flooded with 70% ethanol. Subsequently, metacestodes were stored in 70% ethanol and were mounted in a similar fashion to the adult cestodes. Several heavily infected digestive glands were fixed in 10% neutral buffered formalin. They were then embedded in paraffin and sectioned at a thickness of 5 µm. Sections were stained with haematoxylin and eosin.

Several species of crabs collected at Wynnum were also examined for metacestodes. These comprised 11 *Metopograpsus frontalis* Miers, 1880, 3 *Ancylocheles gravelei* (Sankolli, 1963), 1 *Leptodius exeratus* (H. Milne Edwards, 1834) and 1 *Macromedaeus crassimanus* (H. Milne Edwards, 1867).

All cestode specimens collected have been deposited either in the QM or in the South Australian Museum, Adelaide (SAM).

Terminology for the anatomical features of the cestodes follows Pintner (1913) and Dollfus (1942). The names of the genera *Parachristianella* Dollfus, 1946 and *Prochristianella* Dollfus, 1946 are abbreviated as 'Para.' and 'Pro.' respectively to avoid confusion. Measurements are included for species in which they provide novel information. Measurements were made with an ocular micrometer and are presented in millimetres unless otherwise indicated. In instances where only one or two specimens were available, individual measurements are provided. In cases where additional specimens were available, the measurements are presented as the range followed, in parentheses, by the mean and the number of specimens measured.

In the case of the tentacular armature of very small species, at the limits of resolution of the light microscope and without specimens suitably cleaned for scanning electron microscopy, photographs of the tentacles were taken and measurements were made from the photographs. In these instances, measurements are presented in micrometers, to one decimal point of accuracy.

Identifications of known species are supported by confirmatory illustrations and measurements wherever possible. Instances in which this has not been possible are indicated. The extent of morphological information included in current descriptions depended upon the completeness of information already published. Essentially, additional morphological information has been provided only in instances where it contradicts or adds to data already published.

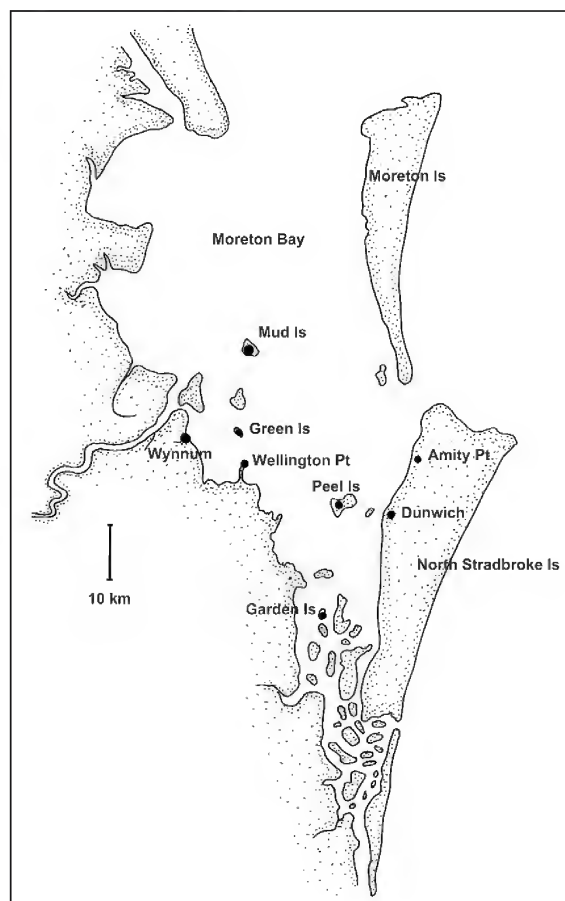


FIG. 1. Moreton Bay region of south-eastern Queensland showing principal collecting localities. Scale bar = 10 km.

Trypanorhynch taxonomy at the superfamily level follows Palm (2004). Family level nomenclature is either unstable or under question (Beveridge *et al.* 2017b) and therefore only superfamily and generic allocations are utilised here.

Within the Eutetrarhynchoidea, genera and species are presented in alphabetical order.

Terminology for prevalence and intensity follows Bush *et al.* (1997).

TABLE 1. Elasmobranchs from Moreton Bay, Queensland, examined for trypanorhynch cestodes.

Host order	Family	Species	N
Selachioidea			
Carcharhiniformes	Carcharhinidae	<i>Carcharhinus cf. limbatus</i> (Valenciennes, 1839)	3
Orectolobiformes	Orectolobidae	<i>Orectolobus maculatus</i> (Bonnaterre, 1788)	1
		<i>Orectolobus ornatus</i> (de Vis, 1883)	1
	Hemiscylliidae	<i>Chiloscyllium punctatum</i> Müller & Henle, 1838	3
Batoidea			
Myliobatiformes	Aetobatidae	<i>Aetobatus ocellatus</i> (Kuhl, 1823)	8
	Dasyatidae	<i>Hemitrygon fluviorum</i> Ogilby, 1908 (formerly <i>Dasyatis fluviorum</i>)	4
		<i>Maculabatis cf. astra</i> (formerly <i>Himantura astra</i>)	3
		<i>Maculabatis toshi</i> Whitley, 1939 (formerly <i>Himantura toshi</i>)	5
		<i>Himantura australis</i> Last, Whyte & Naylor, 2016 (formerly <i>Himantura uarnak</i> Forsskål, 1775)	1
		<i>Neotrygon trigonoides</i> (Castelnau, 1873)	19
		<i>Pastinachus ater</i> (MacLeay, 1883)	1
Rhinopristiformes	Glaucostegidae	<i>Glaucostegus typus</i> (Bennett, 1830)	9
	Trygonorrhinidae	<i>Aptychotrema rostrata</i> (Shaw, 1794)	6
Total			64

TABLE 2. Prevalence and intensity of trypanorhynch plerocerci found in the digestive glands of crustaceans collected in Moreton Bay, Queensland.

Intermediate host	Locality	Date	N	Prevalence (%)	Intensity	Mean Intensity
<i>Typaea australiensis</i>	Dunwich	May 2010	17	82	1–17	5.9
		July 2016	20	65	1–5	2.1
	Wynnum	Nov 2011	54	56	1–3	1.6
<i>Alpheus</i> spp.	Dunwich	Jan 2016	25	52	1–8	3.4
		July 2016	20	85	1–57	16.8
	Wynnum	Nov 2011	70	54	1–17	2.2

RESULTS

A total of 64 elasmobranchs was examined for parasites (Table 1). The collection included three specimens of a ray which was provisionally identified as *M. astra* using the keys in Last and Stevens (2009) (therein as *Himantura astra*) but which had mainly white rather than black spots on its disk. Two of the specimens collected were deposited in QM (1.38898, 1.40746). Tissues from one of these rays was included in a molecular analysis by Naylor *et al.* (2012) and proved to be genetically distinct from the remaining specimens of *H. astra* included in the study. Naylor *et al.* (2012, p. 69) suggested that the morphologically different specimens

warranted further investigation. For this reason they have been identified here as *M. cf. astra*.

Crustaceans (*T. australiensis* and *Alpheus* spp.) collected opportunistically at mudflats at both Dunwich and Wynnum yielded numerous larval eutetrarhynchids in their digestive glands (Table 2). The highest prevalences and intensities of infection found were at Dunwich in July (Table 2). The metacestodes encountered are dealt with in the following taxonomic section.

The alpeid shrimps were identified specifically from a relatively small sample retained from dissections following Banner and Banner (1982). Three voucher specimens retained from Wynnum were *Al. richardsoni* Yaldwyn, 1971 while at Dunwich, a sample of 15 shrimps consisted of 5 *Al. richardsoni* and 10 *Al. papillosus* Banner

Trypanorhynch cestodes (Platyhelminthes)

TABLE 3. Records of trypanorhynch cestodes from elasmobranchs of Moreton Bay, Queensland. Host authorities are provided in Table 1.

Trypanorhynch cestode(s)	Host(s)
Tentacularioidea Poche, 1926	
<i>Kotorella pronosoma</i> (Stossich, 1901)	<i>Maculabatis toshi</i> *
Otobothrioidea Dollfus, 1942	
<i>Proemotobothrium southwelli</i> Beveridge & Campbell, 2001	<i>Glaucostegus typus</i> *
Eutetrarhynchoidea Guiart, 1927	
<i>Dollfusiella owensi</i> (Beveridge, 1990)	<i>Hemitrygon fluviorum</i> *
	<i>Maculabatis toshi</i> *
	<i>Maculabatis cf. astra</i> *
	<i>Neotrygon trigonoides</i> *
<i>Dollfusiella armata</i> sp. nov.	<i>Maculabatis cf. astra</i>
	<i>Maculabatis toshi</i>
<i>Dollfusiella pilosa</i> sp. nov.	<i>Aetobatus ocellatus</i>
<i>Dollfusiella spinulifera</i> (Beveridge & Jones, 2000)	<i>Hemitrygon fluviorum</i> *
	<i>Glaucostegus typus</i>
	<i>Maculabatis toshi</i> *
<i>Dollfusiella</i> sp. 1	<i>Aetobatus ocellatus</i>
	<i>Neotrygon trigonoides</i>
<i>Dollfusiella</i> sp. 2	<i>Aptychotrema rostrata</i>
	<i>Hemitrygon fluviorum</i>
	<i>Glaucostegus typus</i>
<i>Dollfusiella</i> sp. 3	<i>Aptychotrema rostrata</i>
<i>Hispidorhynchus australiensis</i> (Toth, Campbell & Schmidt, 1992)	<i>Aetobatus ocellatus</i>
<i>Parachristianella monomegacantha</i> Kruse, 1959	<i>Hemitrygon fluviorum</i>

Trypanorhynch cestode(s)	Host(s)
	<i>Glaucostegus typus</i> *
Eutetrarhynchoidea Guiart, 1927 cont...	<i>Neotrygon trigonoides</i> *
<i>Parachristianella</i> sp. (undescribed)	<i>Hemitrygon fluviorum</i>
<i>Poecilorhynchus perplexus</i> Schaeffner & Beveridge, 2013	<i>Chiloscyllium punctatum</i>
<i>Prochristianella aciculata</i> Beveridge & Justine, 2010	<i>Hemitrygon fluviorum</i> *
	<i>Maculabatis</i> cf. <i>astra</i> *
	<i>Neotrygon trigonoides</i>
<i>Prochristianella butlerae</i> Beveridge, 1990	<i>Pastinachus ater</i>
	<i>Glaucostegus typus</i> *
<i>Prochristianella clarkeae</i> Beveridge, 1990	<i>Hemitrygon fluviorum</i> *
	<i>Glaucostegus typus</i> *
	<i>Maculabatis toshi</i>
	<i>Maculabatis</i> cf. <i>astra</i> *
	<i>Neotrygon trigonoides</i>
<i>Prochristianella omunae</i> Beveridge & Justine, 2010	<i>Neotrygon trigonoides</i>
<i>Zygorhynchus elongatus</i> Beveridge & Campbell, 1988	<i>Hemitrygon fluviorum</i> *
	<i>Maculabatis</i> cf. <i>astra</i> *
<i>Zygorhynchus robertsoni</i> Beveridge & Campbell, 1988	<i>Aetobatus ocellatus</i> *
	<i>Maculabatis toshi</i> *
<i>Zygorhynchus</i> sp. (undescribed)	<i>Neotrygon trigonoides</i>
* indicates new host record.	

and Banner, 1982. None of the crabs examined was found to be infected with trypanorhynch metacestodes.

SYSTEMATICS

Superfamily TENTACULARIOIDEA Poche, 1926

Genus *Kotorella* Euzet & Radujkovic, 1989

Kotorella pronosoma (Stossich, 1901) (Figs 2-3)

Material examined. 2 specimens, stomach, *Maculabatis toshi*, Green Island (QM G235986-7).

Morphology. Total length 17, 22; Scolex length 0.62, 0.64; pars bothrials 0.34, 0.35; pars vaginalis 0.39, 0.42; bulb length 0.08; bulb width 0.035, 0.045; velum 0.065, 0.070.

Remarks. Although the tentacles of the two specimens were only partially everted, the characteristic scolex (Fig. 2) and proglottis morphology (Fig. 3) permitted identification of the species. The features of the tentacular armature visible were consistent with previous descriptions. Palm (2004, p. 162) remarked on the different sizes and shapes of the scolex in various descriptions of the species. For this reason, an illustration and measurements of the scolex (Fig. 2) are included here. This cosmopolitan species (Palm 2004) has previously been reported from *H. fluviarium* in Moreton Bay (Palm & Beveridge 2002) (as *Dasyatis fluviarium*). Its occurrence in *M. toshi* represents a new host record.

Superfamily OTOBOTHRIOIDEA Dollfus, 1942

Genus *Proemotobothrium* Beveridge & Campbell, 2001

Proemotobothrium southwelli Beveridge & Campbell, 2001 (Figs 4-7)

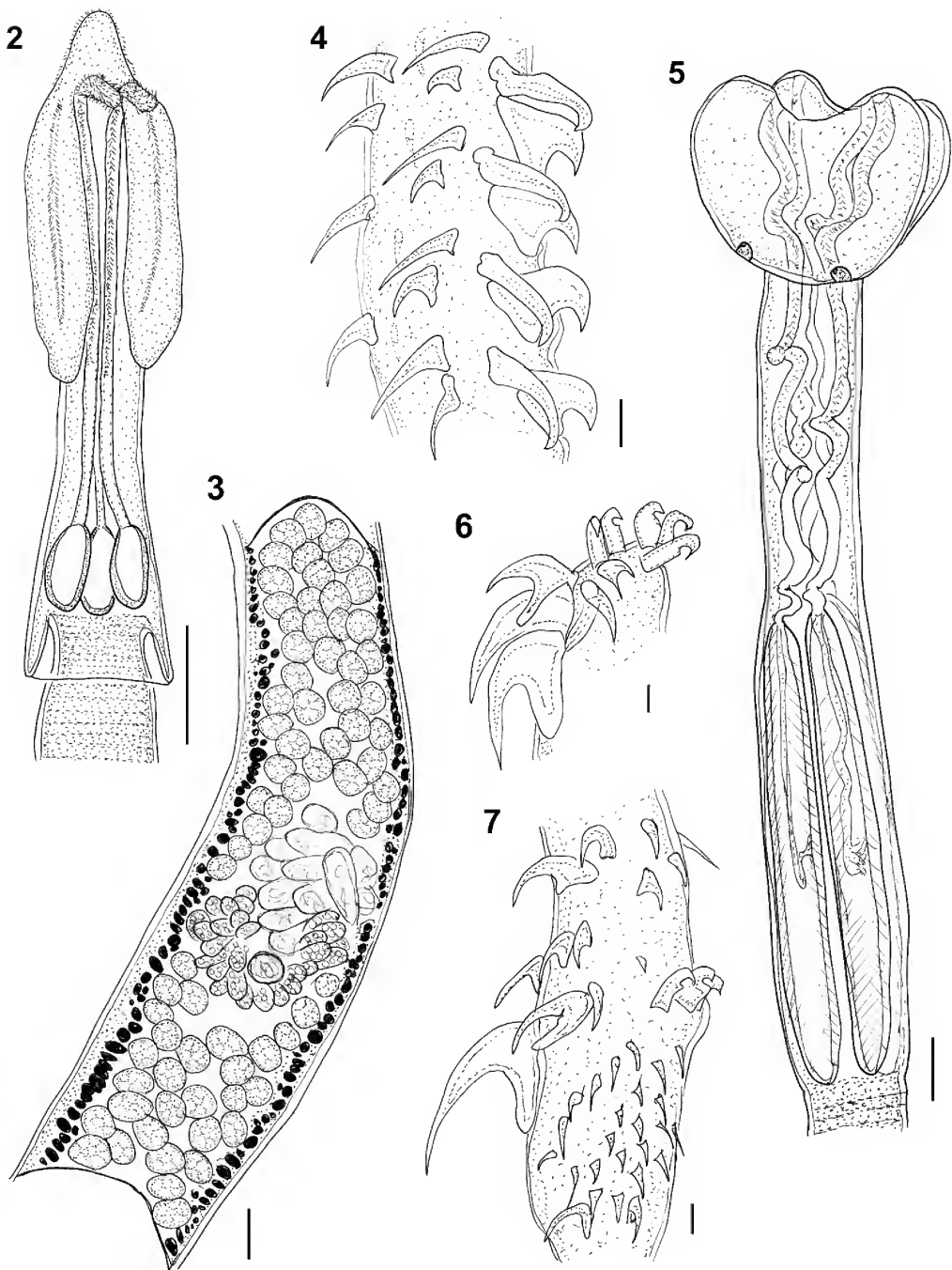
Material examined. 1 specimen, spiral valve, *Pastinachus atrer*, Peel Island (QM 236206); 7 specimens, spiral valve, *Glaucostegus typus*, Garden Island (QM G236208-9), Wynnum North (QM 236210-

14); 1 specimen, spiral valve, *Carcharhinus cf. limbatus*, Green Island (QM G236207).

Morphology. Scolex length 1.58-1.70 (1.69, n=8), scolex width 0.23-0.30 (0.27, n=8), pars bothrials 0.32-0.38 (0.35, n=8), pars vaginalis 0.79-0.89 (0.85, n=8), bulb length 0.75-0.84 (0.79, n=8), bulb width 0.08-0.12 (0.11, n=8), pars postbulbosa absent (Fig. 5); large basal hooks (Figs 6, 7) 80, 45 µm long, base 50, 35 µm long; metabasal armature (Fig. 4): hook 1, 30 µm long, base 25 µm long; hook 2, 28 µm long, base 10 µm long, hook 3, 25 µm long, base 10 µm long, hook 4, 22 µm long, base 10 µm long; hook 5, 22 µm long, base 8 µm long; intercalary hook 25 µm long, base 15 µm long; hook from band on external surface 13 µm long, base 5 µm long.

Remarks. A full description of this species was provided by Beveridge and Campbell (2001) and additional host records were added by Shaeffner and Beveridge (2013a). The only set of measurements for the species are those of the type specimens from *C. limbatus* (see Beveridge & Campbell 2001). The measurements presented here from *G. typus* are generally smaller than those of the original description apart from bulb lengths. However the scolex ratios (Pbo:Pvag:Pbulb) are similar (1: 3.1: 2.3 in the original description; 1: 2.8: 2.3 in the current material) and all other morphological features accord well with the original description.

Glaucostegus typus is a new host for this species and the collections from Moreton Bay extend the previously known Australian distribution from the north west of Western Australia, the Northern Territory, and the Whitsunday Islands and Heron Island in Queensland (Beveridge & Campbell 2001; Beveridge *et al.* 2014) to the south-eastern region of Queensland. Beveridge *et al.* (2017a) reported the plerocercus of this species from the teleosts *Ostorhinchus limenus* (Randall & Hoese, 1984) and *Monacanthus chinensis* (Osbeck, 1765) in Moreton Bay.



FIGS. 2-7. *Kotorella pronosoma* (Stossich, 1901) (2-3) and *Proemotobothrium southwelli* Beveridge & Campbell, 2001 (4-7). 2, scolex, lateral view; 3, mature segment, dorso-ventral view; 4, metabasal armature, antibothrial view, internal surface on right side; 5, scolex, dorso-ventral view; 6, enlarged hooks on basal swelling; 7, basal swelling. Scale bars: Figs. 2,3,5 = 0.1 mm; 4,6,7 = 0.01mm.

Superfamily EUTETRARHYNCHOIDEA
Guiart, 1927

Genus *Dollfusiella* Campbell
& Beveridge, 1994

Dollfusiella armata sp. nov.
(Figs 8-14, 32)

Material examined. Types: holotype, spiral valve, *Maculabatis cf. astra*, Garden Island (QM G235827); 23 paratypes, same data (QM G23528-50). Vouchers: 2 specimens, Wynnum (QM G235851-2); 2 specimens, from spiral valve, *Maculabatis toshi*, Wynnum (QM G235853-4); 2 specimens, Peel Island (QM G235861-2); 3 specimens, Green Island (QM G235855-7); Wellington Point (QM G235864-5) (2 specimens used for SEM).

Morphology (based on type series). Small cestodes, largest immature specimen (holotype), 0.88 long with 3 segments; scolex length 0.56-0.65 (0.61, n=10), scolex narrower in pars vaginalis (Figs 8, 9), 0.05-0.08 (0.06, n=10) wide, broader in pars bulbosa, 0.08-0.14 (0.11, n=10); pars bothriialis 0.10-0.12 (0.11, n=10); pars vaginalis 0.30-0.35 (0.32, n=10); tentacle sheaths sinuous to convoluted; no pigment in scolex anterior to bulbs; bulb length 0.25-0.30 (0.27, n=10), bulb width 0.03-0.05 (0.04, n=10); bulb length: width ratio 5-9 (6.6, n=10); pars postbulbosa very short. Enlarged gladiate microtriches (Fig. 32) cover entire scolex to posterior extremity of pars bulbosa as well as antiothrial surface of bothria; microtriches on scolex peduncle largest in pars vaginalis, diminishing in size posteriorly; largest microtriches 11.4 µm long, with rounded base in dorso-ventral view, 6.5 µm in diameter, in lateral view with bifurcate base (Fig. 14); enlarged microtriches arranged in quincunxial pattern; microtriches on bothria generally smaller, 8.1mm long, but with similar structure.

Tentacular armature. Basal swelling present (Fig. 13), 15-20 µm (17, n=5) in diameter; diameter of tentacle in metabasal region 17mm, in distal region 10-11mm (10.2, n=5). Armature heteroacanthous, heteromorphous, orientation of armature from antiothrial to bothrial surface. Basal armature (Fig. 13): initial row of hooks enlarged, uncinat, 3.4-5.0 µm (4.2, n=5) long, base 1.6-2.5 µm (2.2, n=5) long; anterior

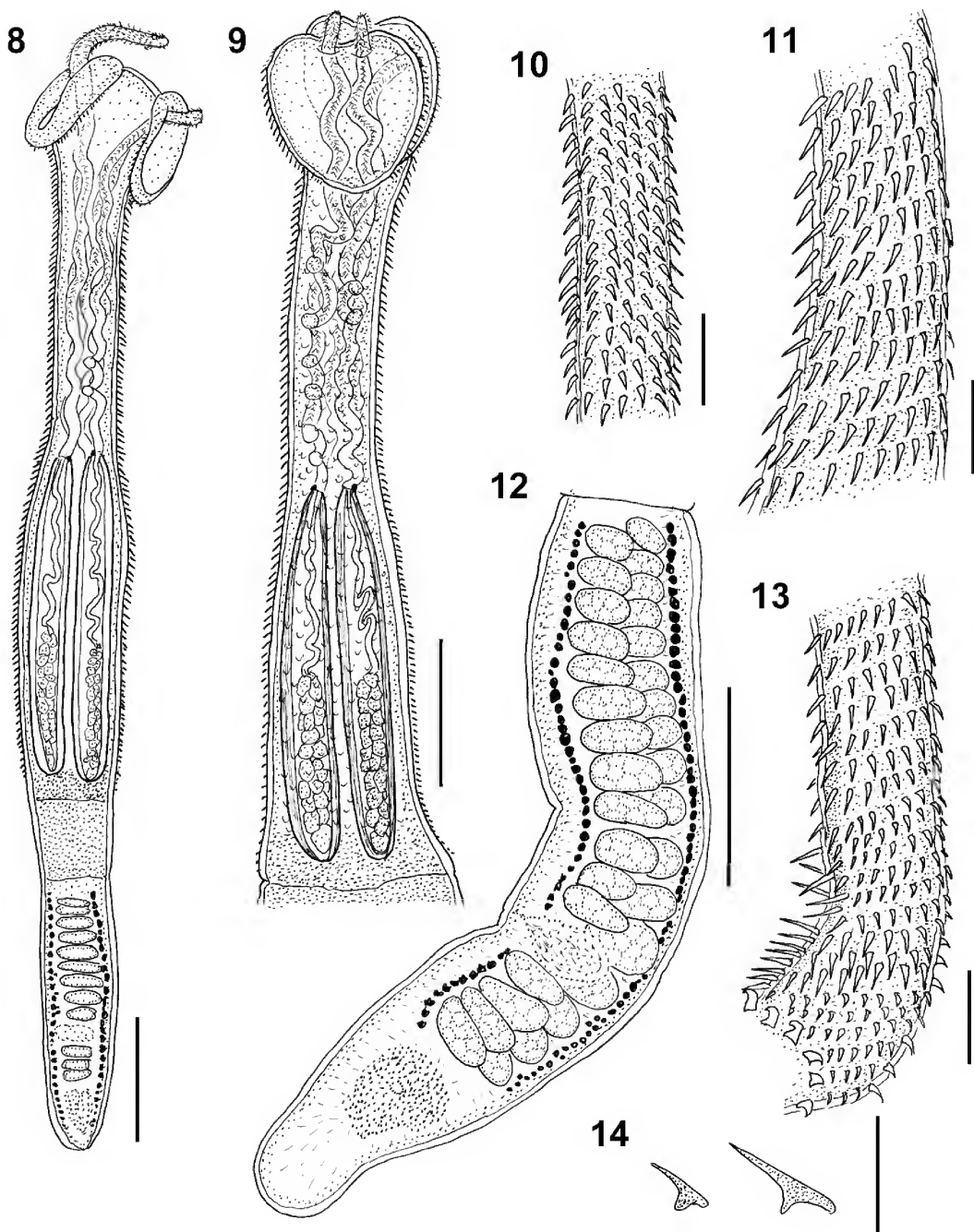
to basal row, hooks initially small, spiniform, 2.0 µm long, base 0.8 µm long; becoming larger anteriorly, 3.4 µm long, base 1.3 µm long; internal surface of basal swelling with elongate spiniform hooks 4.2-6.7 µm (5.3, n=5) long, base 1.3-1.7 µm (1.3, n=5) long; on external surface, hooks uncinat, 3.4-4.2 µm (3.9, n=5) long, base 1.3-1.7 µm (1.6, n=5) long. Metabasal armature: 8-9 hooks per half-spiral in metabasal region (Fig. 11), decreasing to 7-8 in distal region of tentacle (Fig. 10); hooks homeomorphous, spiniform, no apparent change in size on different surfaces of tentacle; in metabasal region hooks 3.8-5.0 µm (4.3, n=5) long, base 0.8-1.3 µm (1.1, n=5) long.

Segments. All specimens immature; single specimen with 4 segments; pre-mature segments 0.15-0.46 (0.25, n=5) long, 0.06-0.13 (0.08, n=5) wide with genital pore in posterior region of segment; testes arranged in 2 columns (Fig. 12); total number of testes 25-33 (28, n=4), with 13-17 (15, n=4) antiporal, 10-12 (11, n=4) pre-vaginal and 2-4 (3, n=4) postvaginal; remaining male and female genitalia not developed; vitelline follicles circum-cortical.

Diagnosis. The description of this species is incomplete due in part to the tiny dimensions of the tentacular armature and the lack of availability of specimens suitable for scanning electron microscopy, as well as the lack of fully mature or gravid specimens. However, the species is unique and clearly identifiable based on the size of the enlarged microtriches arming the scolex and extending to the very base of the scolex. This feature immediately distinguishes it from all congeners apart from *D. imparispinis* Schaeffner and Beveridge, 2013.

Its scolex size (maximum 0.65) distinguishes it from all congeners with enlarged microtriches extending to the base of the scolex, apart from *D. spinulifera* (Beveridge & Jones, 2000), while its bulb length (maximum 0.30) distinguishes it from all comparable congeners apart from *D. spinulifera* and *D. imparispinis*.

In addition, the tiny tentacular armature distinguishes it from all currently known species apart from *D. imparispinis*. It differs from *D. imparispinis* in the basal armature as in *D.*



FIGS. 8-14. *Dollfusiella armata* sp. nov. 8, entire cestode, holotype, lateral view; 9, scolex, dorso-ventral view; 10, tentacular armature, distal region; 11, tentacular armature, metabasal region; 12, mature proglottis; 13, basal armature, external surface, antibothrial surface on left side; 14, profile of enlarged microtriches from pars vaginalis and bothrium. Scale bars: Figs 8, 9, 12 = 0.1 mm; 10, 11, 13, 14 = 0.01 mm.

imparispinis, there is an extensive area with few hooks between the enlarged hooks at the very base and the rows of erect spiniform hooks and in the metabasal region, the hooks of the current species are relatively homeomorphous in contrast to those in *D. imparispinis* which are highly heteromorphous. In addition, *D. imparispinis* has 35-48 testes (Schaeffner & Beveridge 2013c) compared with 25-33 in the current species. *Dollfusiella imparispinis* has been found only in the orectolobiform shark *Chiloscyllium punctatum* off Borneo (Schaeffner & Beveridge 2014), while the present species was found primarily in dasyatid rays. The three *Ch. punctatum* examined in Moreton Bay (Table 1) were not infected with the species.

In spite of the obvious limitations in the description, the species has been named in the expectation that future collecting will enable more complete description based on features observable using scanning electron microscopy.

***Dollfusiella owensi* (Beveridge, 1990)**
(Figs 15-18, 33-34)

Material examined. 16 specimens, spiral valve, *Maculabatis toshi*, Peel Island (QM G235866-75), Green Island (QM G235876-9); 9 specimens, spiral valve, *Maculabatis cf. astra*, Garden Island (QM G235882-4), Wynnum North (QM G235888-93); 6 specimens, spiral valve, *Hemirhynchus fluviorum*, Wynnum North (QM G235880 -1); 3 specimens, spiral valve, *Neotrygon trigonoides*, Wynnum North (QM G235885-7).

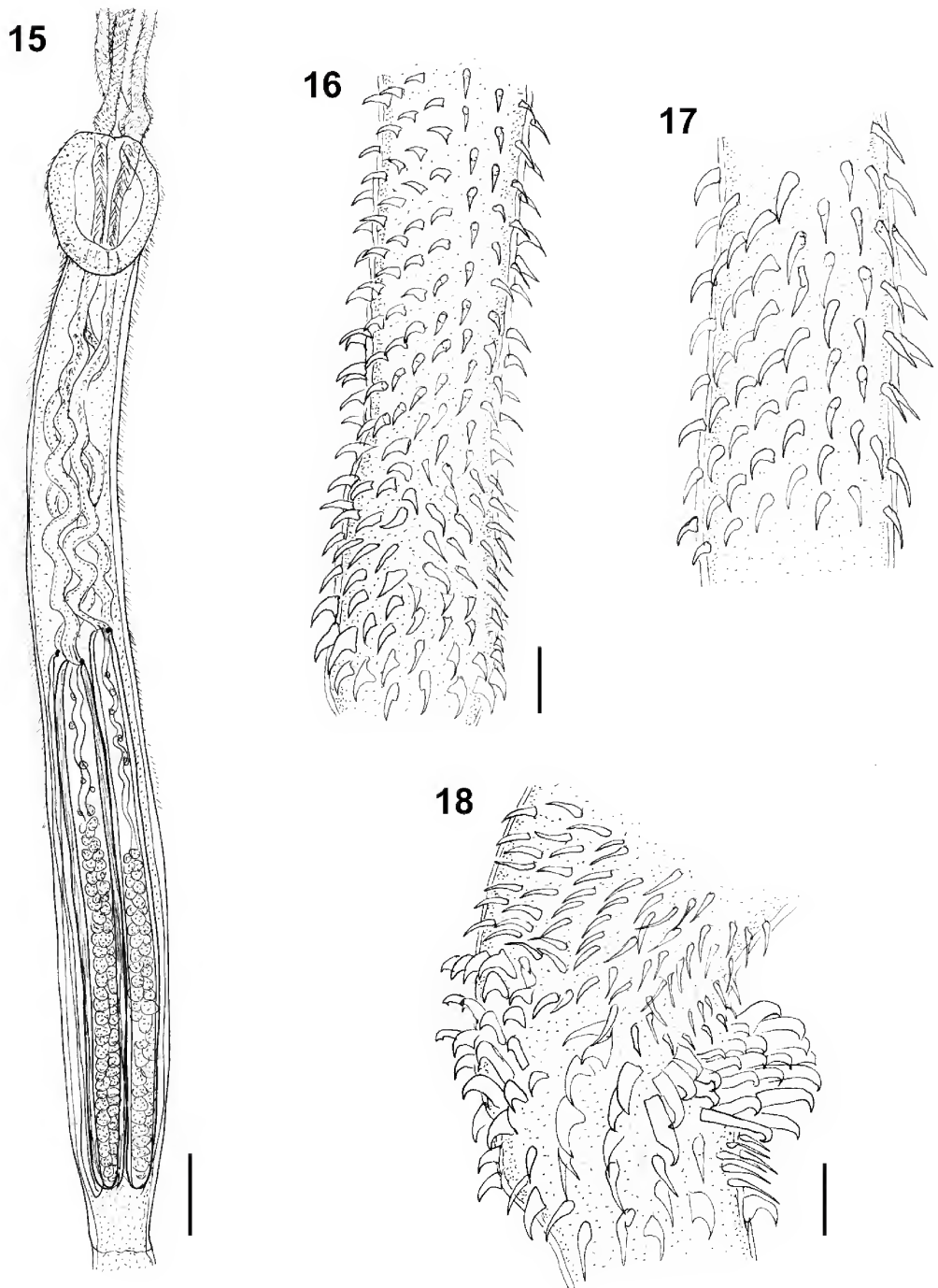
Morphological features. Scolex measurements of specimens from *M. toshi*: scolex length 1.22-1.45 (1.30, n=6) (Fig. 15), scolex width 0.06-0.15 (0.11, n=6) in pars vaginalis, 0.15-0.21 (0.17, n=6) in pars bulbosa; pars bothrials 0.16-0.24 (0.19, n=6); pars vaginalis 0.54-0.70 (0.63, n=6); bulb length 0.59-0.71 (0.65, n=6); bulb width 0.05-0.08 (0.06, n=6), pars postbulbosa absent. Enlarged gladiate microtriches present on scolex (Fig. 34) to level of pars bulbosa and on internal aspects of bothria (Fig. 33). Armature: metabasal armature begins on antiothrial surface, terminates on bothrial surface. Hooks in metabasal region hollow, arranged in ascending half circles (Figs 16, 17), spiniform, varying in size from 0.026-0.032 (0.029, n=10) long with base 0.007-0.014 (0.010, n=10) long on

antiothrial surface to 0.016-0.021 (0.018, n=10) long, with base 0.003-0.007 (0.005, n=10) long on bothrial surface; in basal region, cluster of enlarged bill-hooks on antiothrial surface (Fig. 18).

Remarks. *Dollfusiella owensi* was described by Beveridge (1990) from *H. australis* (as *H. uarnak*) and *N. leylandi* (Last, 1987) (as *Dasyatis leylandi*) from the Northern Territory. The original report of the species from *N. leylandi* is now questionable as the distribution of this species has been reduced. Formerly reported as occurring across northern Australia from Townsville in Queensland to the Monte Bello Islands in Western Australia (Last & Stevens 1994, p. 394) it is now considered to be restricted to an area off the northern Western Australian coast (Last & Stevens 2009, p. 454). The correct host may be the more recently described species *Neotrygon picta* Last and White, 2008, which was formerly included within *N. leylandi*.

This cestode species is readily recognisable as the enlarged microtriches of the scolex extend to the anterior region of the pars bulbosa and the bill-hooks on the antiothrial surface of the basal swelling are extremely prominent (Fig. 18). In the original description (Beveridge 1990), the enlarged microtriches were described as covering the anterior two thirds of the pedunculus scolecis. The electron micrographs presented here provide novel information on the morphology of the enlarged gladiate microtriches in this species (Fig. 34). It would have been clearer to have described them as extending into the anterior region of the pars bulbosa (Fig. 15). Using the key of Schaeffner and Beveridge (2013c), *D. owensi* is most similar to *D. angustiformis* Schaeffner and Beveridge, 2013 but the latter species differs in lacking the very large bill-hooks on the basal swelling. The current specimens are slightly larger than those of the original description, requiring some alteration to couplet 25 in the key of Schaeffner and Beveridge (2013c).

The metabasal armature originates on the antiothrial surface of the tentacle and terminates on the bothrial surface, as in other congeners in which this feature has been examined closely



FIGS. 15-18. *Dollfusiella owensi* (Beveridge, 1990). 15, scolex, dorso-ventral view; 16, basal armature, bothrial surface, external surface on left; 17, metabasal armature, bothrial surface on left; 18, basal armature, bothrial surface on left. Scale bars: Fig.15 = 0.1 mm; 16-18 = 0.01 mm.

(Schaeffner & Beveridge 2013c). In the original description (Beveridge 1990), the armature was described under the assumption that hook rows ran invariably from the internal to the external surface.

Apart from extending the host range to include *M. toshi*, *M. cf. astra* and *H. fluviarium* (all new host records), the current collection also extends the geographical range of the species from the Northern Territory (Beveridge 1990) to south-eastern Queensland.

***Dollfusiella pilosa* sp. nov.**
(Figs 19-23)

Material examined. Holotype, spiral valve, *Aetobatus ocellatus*, Wynnum North (QM G235894); 5 paratypes, same data (QM G235895-9).

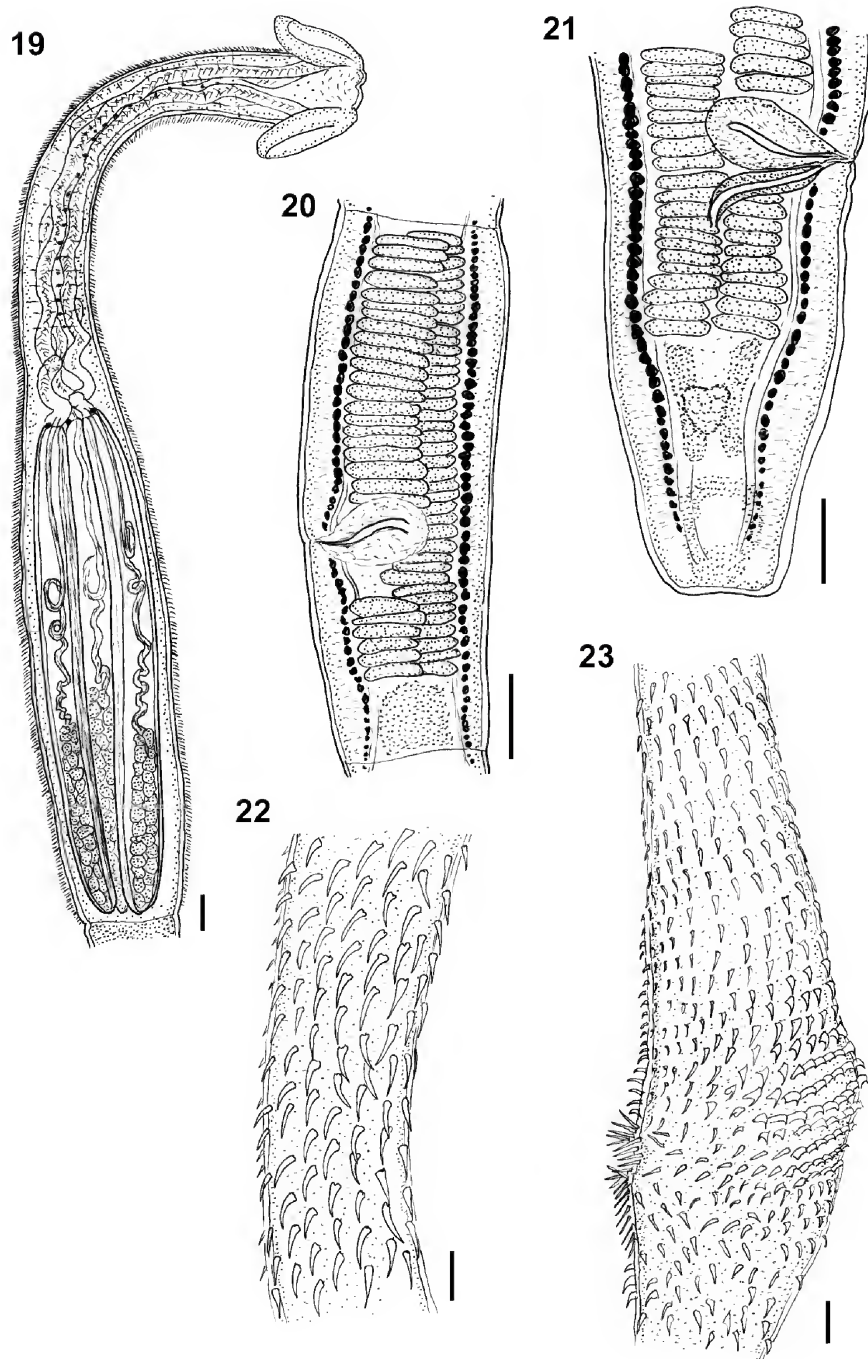
Description. Scolex acraspedote (Fig. 19), 2.40-3.52 (3.00, n=5) long, 0.18-0.30 (0.23, n=5) wide in pars vaginalis, 0.38-0.44 (0.41, n=5) wide in pars bulbosa; scolex covered with enlarged microtriches to distal end (Fig. 19); enlarged microtriches readily lost in poorly fixed specimens; 2 patelliform bothria, pars bothrialis 0.23-0.40 (0.30, n=5); pars vaginalis 1.49-2.08 (1.63, n=5), sheaths sinuous, Pintner's cells prominent; bulbs 1.10-1.57 (1.34, n=5) long, 0.13-0.15 (0.13, n=5) wide, bulb length: width ratio 8.5-12.0 (10.0, n=5); prebulbar organ present; retractor muscle originates at base of bulb; gland cells present within bulb; pars post-bulbosa absent. Tentacles up to 0.97 long; 30-33 μm (33, n=4) in diameter in distal region of tentacle; basal swelling present, 35-50 μm (45, n=4) in diameter (Fig. 23).

Tentacular armature. Distinctive basal armature present. Metabasal armature heteroacanthous, relatively homeomorphous (Fig. 22); hooks hollow; hook rows begin on antibothrial surface, terminate on bothrial surface; 9-10 hooks per half spiral. Hooks slender, spiniform with slight size gradient; hooks on bothrial surface 72-88 μm (79, n=5) long, base 10-20 μm (16, n=5) long; on external surface, slightly longer, 92-104 μm (98, n=5) long, base 20-28 μm (22, n=5) long, diminishing in size on antibothrial surface, 52-64 μm (59, n=5) long, base 12-16 μm (14, n=5) long. On basal swelling, initial 10 rows of hooks uncinata to spiniform, not enlarged,

44-64 μm (53, n=5) long, base 20-28 μm (n=5) long; following 8-9 rows commence as erect, elongate, spiniform hooks on antibothrial surface, 52-56 μm (53, n=5) long, base 8-12 μm (9, n=5) long, becoming short and spiniform on external surface, 36-56 μm (45, n=5) long, base 12-16 μm (13, n=5) long and terminating on bothrial surface as bill-hooks 40-60 μm (48, n=5) long, base 12-24 μm (19, n=5) long; in anterior basal region, hooks spiniform with only slight size difference around tentacle, 40-48 μm (45, n=5) long with base 12-20 μm (14, n=5) long on bothrial surface and 36-40 μm (38, n=5) long with base 8-12 μm (10, n=5) long on antibothrial surface.

Segments. Single portion of strobila 14 segments long, immature; largest intact segment 0.67 long, 0.23 wide; genital pore 0.28 from posterior extremity; testes arranged in 2 columns (Fig. 20), 74 in number, with 21 pre-poral, 7 post-poral and 46 antiporal; cirrus sac large, ellipsoidal, 0.15 long, 0.07 wide, no seminal vesicles visible (Fig. 21); vagina opens to genital atrium posterior to cirrus sac; distal vaginal wall greatly thickened; ovary and Mehlis' gland not developed; vitelline follicles circum-cortical.

Diagnosis. The specimens studied represent a new species. The possession of enlarged microtriches extending to the posterior end of the scolex distinguishes the species from all congeners apart from *D. aculeata* (Beveridge, Neifar & Euzet, 2004), *D. acuta* (Menoret & Ivanov, 2015), *D. imparispinis*, *D. litocephala* (Heinz & Dailey, 1974), *D. micracantha* (Carvajal, Campbell & Cornford, 1976), *D. ocallaghani* (Beveridge, 1990), *D. owensi*, *D. spinifer* (Dollfus, 1969), *D. spinosa* (Schaeffner & Beveridge, 2013), *D. taminii* (Menoret & Ivanov, 2014) and *D. tenuispinis* (Linton, 1890). All of these species except *D. litocephala* have bulb lengths shorter than 0.88 μm (compared with 1.10-1.60 μm in the current species and (apart from *D. litocephala* and *D. spinifer*), scolex lengths shorter than 1.68 μm (2.4-3.5 μm in the current species). *Dollfusiella litocephala* has filiform microtriches on the scolex which are much less robust than those encountered in the current species and has much larger bulbs (ie. 2.4-3.4 μm) (Beveridge *et al.* 2004). *Dollfusiella spinifer*,



FIGS. 19-23. *Dollfusiella pilosa* sp. nov. 19, Scolex, lateral view; 20, near-mature segment; 21, posterior extremity of mature segment; 22, metabasal armature, bothrial surface on left; 23, basal armature, bothrial surface on left. Scale bars: Figs. 19-21 = 0.1 mm; 22-23 = 0.01 mm.

apart from having shorter bulbs, possesses enlarged hooks at the base of the tentacle (Beveridge *et al.* 2004) which are lacking in the current species. The strobilar material of this species is both limited and fragmentary, but key features such as the testis number and the basic features of the cirrus sac and vagina are discernible.

The species described here has been named in spite of the material available being insufficient to provide a full description of the tentacular armature and the only specimen with premature segments (Figs 20, 21) lacks the pars bothriialis and tentacles although in every other respect it resembles the specimen from the same host individual as well as the specimens from the other two individual rays infected. Nevertheless, the distinctiveness of the species is clear and additional morphological details can be added with the collection of additional specimens.

This species has been found only in *Ae. ocellatus* in Moreton Bay thus far. A congener, *D. aetobati* (Beveridge, 1990) has similarly been found only in *Ae. ocellatus* in northern Australia. The two species are immediately distinguishable as *D. aetobati* lacks enlarged microtriches on the scolex and differs in scolex measurements.

Dollfusiella spinulifera
(Beveridge & Jones, 2000)

Material examined. 22 specimens, spiral valve, *Glaucostegus typus*, Peel Island (QM G235902-10), Garden Island (QM G235911-2), Wynnum North (QM G235900 -1); 2 specimens, spiral valve, *Hemitygon fluviurum*, Wynnum North (QM G235913-5); 1 specimen, spiral valve, *Maculabatis toshi*, Wellington Point (QM G235916).

Morphological features. Scolex measurements of specimens from *G. typus*: scolex length 0.41-0.55 (0.50, n=10), scolex width 0.08-0.14 (0.11, n=10), pars bothriialis 0.08-0.11 (0.10, n=10), pars vaginalis 0.22-0.29 (0.27, n=10), bulb length 0.16-0.25 (0.22, n=10), bulb width 0.03-0.05 (0.05, n=10); pars postbulbosa absent.

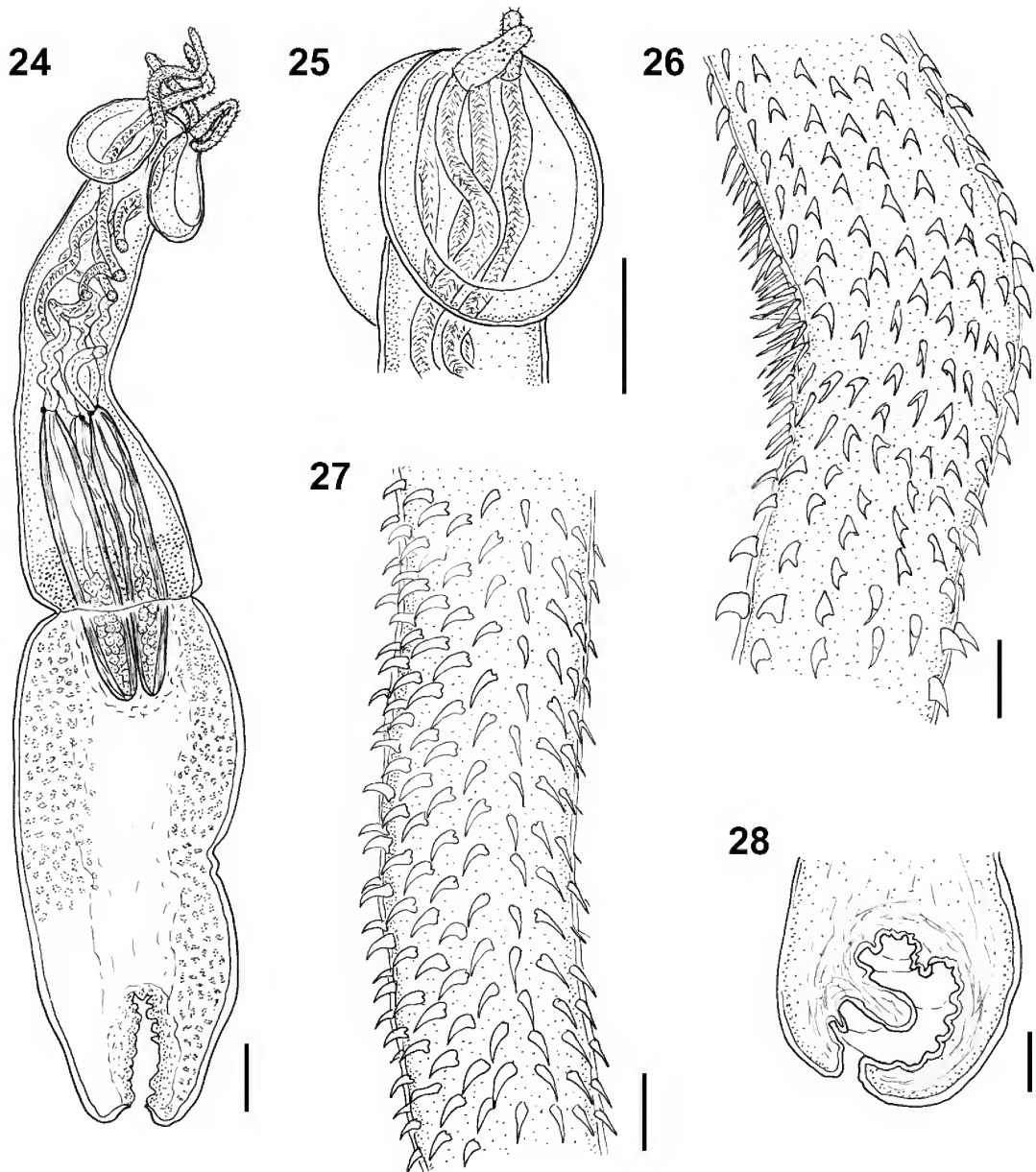
Remarks. *Dollfusiella spinulifera* was initially described from *Glaucostegus typus* (as *Rhynchobatus typus*) (type host) and *Pateobatis fai* (Jordan &

Seale, 1906) (as *Himantura fai*) from Heron Island, Queensland (Beveridge & Jones 2000). This species is readily recognisable by its small size, the extension of the enlarged microtriches to the posterior region of the scolex and the tiny hooks. The range of measurements provided here is similar to that of the original description (Beveridge & Jones 2000). Schaeffner and Beveridge (2013c) extended the geographical range of the species to Borneo as well as adding eight new host species. They recognised the species as being quite variable with two populations based on scolex and bulb lengths. The current species falls at the lower end of the measurement ranges reported by Schaeffner and Beveridge (2013c). The species is readily recognisable by its small size and the extension of the enlarged microtriches to the posterior region of the scolex. The current report expands the geographical range of the species further south from Heron Island (Beveridge & Jones 2000) to Moreton Bay and further expands the host range to include *H. fluviurum* and *M. toshi*. However, the current specimens provide no additional morphological data beyond that described by Beveridge and Jones (2000) and consequently no additional illustrations have been provided.

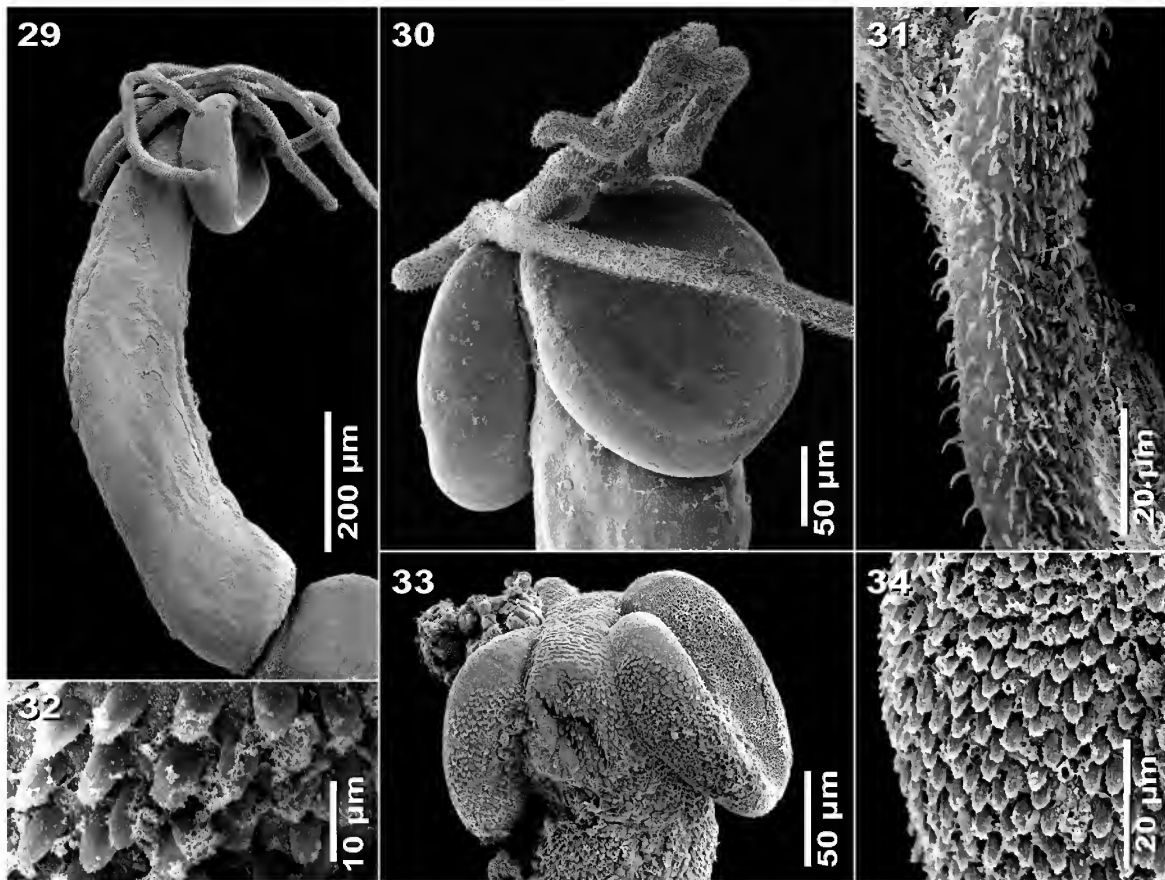
Dollfusiella sp. nov. 1
(Figs 24-31)

Material examined. 34 plerocerci, digestive gland, *Trypaea australiensis*, Wynnum (SAM 36324, QM G 235938-46); 9 plerocerci, Dunwich (QM G235930-7); 1 specimen, digestive gland, *Alpheus richardsoni*, Wynnum (QM G235947); 2 specimens (1 plerocercus, 1 adult scolex), spiral valve, *Neotrygon trigonoides*, Amity Point (QM G235917-8); 1 immature adult, spiral valve, *Neotrygon trigonoides*, Wynnum North (QM G235919); 1 scolex, spiral valve, *Aetobatus ocellatus*, Wynnum (QM G 235920).

Description. (From plerocerci in digestive gland of *T. australiensis*): Scolex length 0.80-1.10 (0.97, n=10) (Figs 24, 29); maximum scolex width in posterior region of bulbs, 0.19-0.27 (0.23, n=10); 2 bothria, semicircular in lateral view (Figs 25, 30), pars bothriialis 0.17-0.24 (0.21, n=10), pars vaginalis 0.48-0.60 (0.54, n=10), tentacular sheaths sinuous; bulbs elongate, length, 0.37-0.55 (0.47, n=10) width 0.05-0.06 (0.05, n=10), bulb length: width ratio 6.2-13.8 (9.1, n=10);



FIGS. 24-28. *Dollfusiella* sp. 1, metacystodes from *Typaea australiensis*. 24, entire plerocercus; 25, bothria of plerocercus, dorsal view; 26, basal armature, bothrial surface on right; 27, metabasal armature, bothrial surface on right; 28, pygidium, dorso-ventral view. Scale bars: Figs. 24, 25, 28 = 0.1 mm; 26-27 = 0.01 mm.



FIGS. 29-34. Scanning electron micrographs. 29 – 31, *Dollfusiella* sp. 1, metacestode from *Typaea australiensis*. 29, scolex; 30, bothrium; 31, metabasal region of tentacle. 32, *Dollfusiella armata* sp. nov., gladiate spinitriches on scolex peduncle; 33 – 34, *Dollfusiella owensi* (Beveridge, 1990); 33, pars bothrialis, dorso-ventral view; 34, gladiate spinitriches on scolex peduncle.

no pigment in anterior region of bulbs; pars post-bulbosa absent; blastocyst 0.78-1.35 (0.98, $n=10$) long, 0.28-0.49 (0.37, $n=10$) wide, without prominent transverse striations (Fig. 24); pygidium prominent with corrugated walls, laterally elongated (Fig. 28), 0.12-0.21 (0.16, $n=7$) long; blastocyst with numerous prominent calcareous corpuscles (Fig. 24).

Tentacular armature. Tentacles with prominent basal swelling and distinctive basal armature (Fig. 26); basal swelling 20-25 μm (21, $n=10$) in diameter; diameter of tentacle in metabasal region 13-18 μm (15, $n=10$). Armature heteroacanthous, heteromorphous, commencing on antibothrial surface, terminating on bothrial surface; meta-

basal armature with c. 8 hooks per half circle (Fig. 27); hooks erect, spiniform with short base (Figs 27, 31), 4.0-6.4 μm (5.3, $n=5$) long, base 1.2-2.8 μm (1.8, $n=5$) long; slight decrease in hook size from antibothrial to bothrial surface; initial rows of hooks at base uncinata (Fig. 26), enlarged, 5.2-8.0 μm (6.2, $n=5$) long, base 2.8-4.0 μm (3.5, $n=5$) long; subsequent rows of hooks spiniform with elongated base, 4.0-4.8 μm (4.4, $n=5$) long, base 2.8-4.4 μm (3.4, $n=5$) long; rows commence on antibothrial surface with cluster of erect spiniform hooks with very narrow base, 6.0-6.8 μm (6.4, $n=5$) long, base 0.8-1.2 μm (0.9, $n=5$) long; rows terminate on bothrial surface with uncinata hooks 4.8-5.2

μm (5.0, $n=5$) long, base 2.0–3.6 μm (2.6, $n=5$) long (Fig. 26).

Remarks. This species of *Dollfusiella* is readily recognisable in the larval stage by its non-striated blastocyst, prominent pygidium (Figs 24, 28) and the lack of any pigment in the scolex at the junction of the tentacle sheaths and the bulbs. It is also distinguishable from the other species of *Dollfusiella* encountered in crustaceans in the length of the tentacular bulbs. It appears to represent an undescribed species within the genus. Currently known congeners lacking enlarged tegumental microtriches on their scolex are: *D. aetobati*, *D. australis* (Prudhoe, 1969), *D. bareldsi* (Beveridge, 1990), *D. caryoni* (Dollfus, 1942), *D. geraschmidtii* (Dollfus, 1974), *D. lineata* (Linton, 1909), *D. macrotrachela* (Heinz & Dailey, 1974), *D. martini* (Beveridge, 1990), *D. musteli* (Carvajal, 1974), *D. vooremi* (São Clemente & Gomes, 1989) and *D. qeshmiansis* Haseli and Palm, 2015. Mean scolex lengths and bulb lengths (Beveridge *et al.* 2004; Schaeffner & Beveridge 2013c; Haseli & Palm 2015) of these species eliminate all congeners other than the Australian species *D. aetobati*, *D. bareldsi* and *D. martini*. *Dollfusiella aetobati* and *D. bareldsi* have 14 hooks per half spiral in the metabasal region compared with eight in the current species. While *D. martini* has five to six hooks per half spiral, it lacks enlarged hooks at the base. Consequently, the current species appears to be undescribed.

The material of this species obtained from elasmobranchs was extremely limited. One specimen from *N. trigonoides* is a newly evaginated plerocercus, with the characteristic pygidium as well as the tentacular armature and the scolex measurements clearly identifying it as this species. The second specimen from the same locality was a scolex, but clearly belongs to the same species. The specimen from Wynnum North from the same host, *N. trigonoides* (QM G235919), was very poorly preserved, but appears to belong to the same species. In this specimen, pre-mature segments are present with c. 40 testes but development of the female genitalia and other internal features are not discernable. A single scolex probably

attributable to this species was also found in one *Ae. ocellatus* examined.

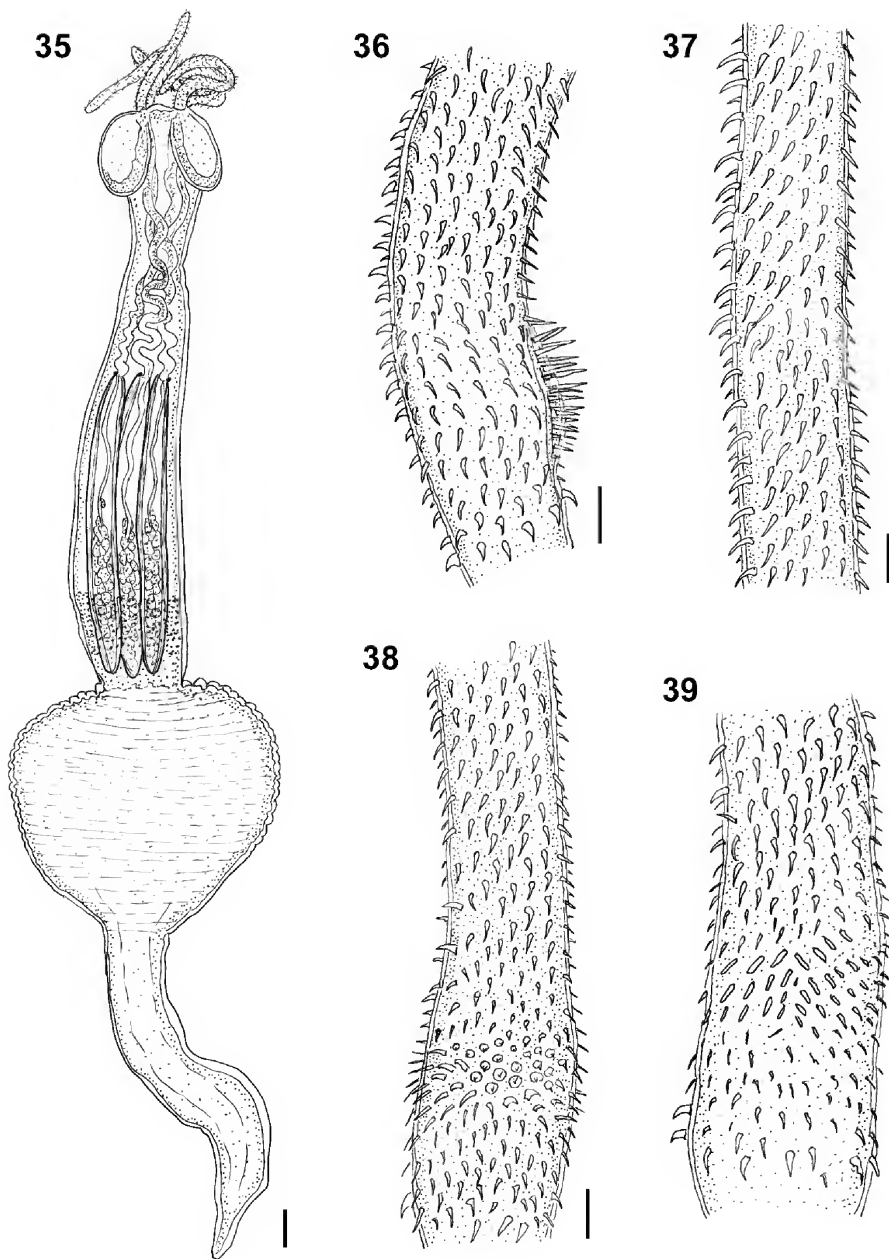
Although a reasonably complete description of the plerocercus can be given, and the probable definitive hosts identified, the inability to provide a more detailed description of the adult precludes naming this evidently new species.

Dollfusiella sp. nov. 2 (Figs 35–39)

Material examined. 7 plerocerci, digestive gland, *Al. richardsoni*, Wynnum (SAM 36325); 19 plerocerci, digestive gland, *Al. papillosus*, Dunwich (QM G236948–65); 1 scolex, spiral valve, *Aptychotrema rostrata*, Wynnum (QM G235921); 3 scoleces, spiral valve, *Glaucostegus typus*, Wynnum North (QM G235922–3), Peel Island, (QM G235924); 3 scoleces, spiral valve, *Hemitrygon fluviorum*, Wynnum North (QM G235925–7).

Description. Plerocerci: scolex length 1.10–1.45 (1.32, $n=10$); maximum scolex width in posterior region of bulbs, 0.24–0.38 (0.30, $n=10$); 2 bothria, semicircular in lateral view (Fig. 35), pars bothrialis 0.20–0.28 (0.24, $n=10$), pars vaginalis 0.63–0.72 (0.67, $n=10$), tentacular sheaths sinuous; bulbs elongate, length, 0.65–0.82 (0.72, $n=10$) width 0.07–0.11 (0.09, $n=10$), bulb length: width ratio 6.3–10.6 (8.2, $n=10$); pale pink pigment in anterior region of bulbs; pars post-bulbosa absent; blastocyst with distinct anterior and posterior portions (Fig. 35); posterior portion lost in most mounted specimens; anterior portion oval to sub-circular when mounted, 0.45–0.75 (0.63, $n=10$) long, 0.55–0.72 (0.62, $n=10$) wide, with prominent transverse striations (Fig. 35); posterior portion elongate tapering distally, up to 0.99 long; pygidium inconspicuous c. 0.14 long (Fig. 35); blastocyst without numerous prominent calcareous corpuscles.

Tentacular armature. Tentacles with slight basal swelling and distinctive basal armature (Figs 38–39); basal swelling 23–38 μm (30, $n=10$) in diameter; diameter of tentacle in metabasal region 20–28 μm (24, $n=10$). Armature heteroacanthous, heteromorphous, commencing on antiothrial surface, terminating on bothrial surface; metabasal armature with c. 8 hooks per half circle (Fig. 37), hooks erect, spiniform with



FIGS. 35-39. *Dollfusiella* sp. 2 metacestodes from *Alpheus* spp. 35, plerocercus; 36, basal armature, external surface, bothrial surface on left side; 37, metabasal armature, external surface, bothrial surface on right side 38, basal armature, antibothrial surface; 38, basal armature bothrial surface. Scale bars: Fig. 35 = 0.1 mm; 36-39 = 0.01 mm.

short base, 5.6–8.0 μm (6.5, $n=5$) long, base 1.6–2.4 μm (1.8, $n=5$) long; no obvious change in hook size from antibothrial to bothrial surface; basal armature: initial rows of hooks at base uncinata, enlarged, 4.0–4.8 μm (4.5, $n=5$) long, base 2.4–3.2 μm (2.6, $n=5$) long; subsequent rows of hooks spiniform with narrow base, 4.0–5.6 μm (4.6, $n=5$) long, base 0.8 μm (0.8, $n=5$) long; rows commence on antibothrial surface with cluster of erect spiniform hooks with very narrow base, 6.4–8.8 μm (7.8, $n=5$) long, base 0.8–1.6 μm (1.4, $n=5$) long; rows terminate on bothrial surface with uncinata hooks 4.8–5.6 μm (5.1, $n=5$) long, base 2.4–3.2 μm (2.7, $n=5$) long.

Remarks. This species of *Dollfusiella* is readily recognizable in the larval stage with its bipartite blastocyst, the prominent transverse striations on the anterior part of the blastocyst and the vermiform posterior part of the blastocyst (Fig. 35). It differs from *Dollfusiella* sp. nov. 1 in having larger scolex measurements, particularly the lengths of the bulbs which do not overlap. This species appears to be undescribed as the scolex and bulb lengths lie outside the ranges of any of the known species of *Dollfusiella* lacking enlarged microtriches on the scolex (see above). Consequently, it appears that this species is also novel. Adults of this species, represented by scoleces only were recovered from the spiral valves of *Ap. rostrata*, *G. typus* and *H. fluviatorum*, but the lack of mature segments and details of the anatomy of the adult prevent the naming of this evidently new species.

Dollfusiella sp. nov. 3 (Figs 40–42)

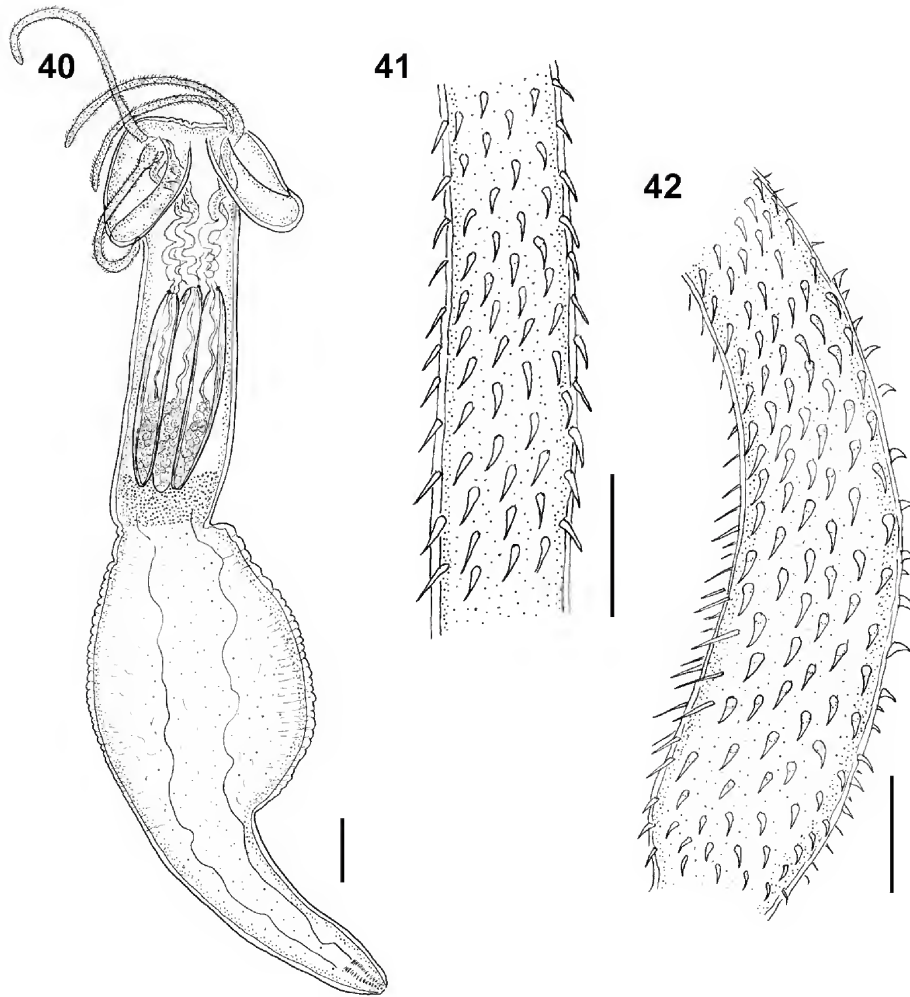
Material examined. 9 plerocerci, digestive gland, *Alpheus* sp., Wynnum (SAM 36326; QM G235976–9); 2 scoleces, spiral valve, *Aptychotrema rostrata*, Amity Point (QM G235928–9).

Description. Plerocerci: scolex length 0.60–0.73 (0.67, $n=9$) (Fig. 40); maximum scolex width in posterior region of bulbs, 0.14–0.20 (0.17, $n=9$); 2 bothria, semicircular in lateral view, pars bothrialis 0.19–0.23 (0.21, $n=9$), pars vaginalis 0.30–0.43 (0.35, $n=9$), tentacular sheaths sinuous; bulbs elongate, length, 0.26–0.32 (0.30, $n=9$), width 0.04–0.06 (0.05, $n=9$), bulb length: width ratio 5.2–6.4 (5.9, $n=9$); no pigment noted in

anterior region of bulbs; pars post-bulbosa up to 0.08 (0.02, $n=9$) long; blastocyst elongate, tapering posteriorly (Fig. 40), 0.45–0.95 (0.73, $n=8$) long, 0.20–0.37 (0.32, $n=8$) wide; pygidium inconspicuous; blastocyst without numerous prominent calcareous corpuscles.

Tentacular armature. Tentacles with slight basal swelling and distinctive basal armature (Fig. 42); basal swelling 13–18 μm (15, $n=9$) in diameter; diameter of tentacle in metabasal region 10–15 μm (10, $n=9$). Armature heteroacanthous, heteromorphous, commencing on antibothrial surface, termination on bothrial surface; metabasal armature with c. 6 hooks per half circle (Fig. 41), hooks erect, spiniform with short base, 2.0–2.8 μm (2.4, $n=5$) long, base 0.4–0.8 μm (0.6, $n=5$) long; no obvious change in hook size from antibothrial to bothrial surface; basal armature: initial rows of hooks at base uncinata, not enlarged (Fig. 42); subsequent rows of hooks spiniform with narrow base, 2.0–2.8 μm (2.2, $n=5$) long, base 0.4–0.8 μm (0.6, $n=5$) long; rows commence on antibothrial surface with cluster of erect spiniform hooks with very narrow base, 3.6–4.8 μm (4.1, $n=5$) long, base 0.4 μm (0.4, $n=5$) long; rows terminate on bothrial surface with uncinata hooks 1.6–2.4 μm (2.0, $n=5$) long, base 0.8–1.6 μm (1.2, $n=5$) long.

Remarks. This species of *Dollfusiella* is much smaller than any of the metacestodes described above, differing in scolex measurements and particularly in the dimensions of the bulbs and the bulb ratio. The tentacular armature is also much smaller although it has the same general pattern as the previously described larval species. As with the previous species, this species is apparently undescribed as scolex and bulb measurements are smaller than any of the known species of this genus. Scoleces of the adults were found in the spiral valve of *Ap. rostrata*, but since mature segments were not present, the new species is not named here.



FIGS. 40-42. *Dollfusiella* sp. 3, plerocercus from *Alpheus* spp. **40**, plerocercus, lateral view; **41**, metabasal armature **42**, basal armature, external surface, bothrial surface on right side. Scale bars: Fig. 40 = 0.1 mm; 41-42 = 0.01 mm.

Genus *Hispidorhynchus* Schaeffner & Beveridge, 2012

***Hispidorhynchus australiensis* (Toth, Campbell & Schmidt, 1992)**

Material examined. 3 specimens, spiral valve, *Aetobatus ocellatus*, Wynnum North (QM G235983-5).

Remarks. This species has been described previously from *Ae. ocellatus* under its former

name, *Ae. narinari*, from the Northern Territory (Toth *et al.* 1992; Campbell & Beveridge 2009). As there is a recent redescription of the species (Campbell & Beveridge 2009), no additional morphological data are provided here. The current record extends the geographical distribution of the species from the Northern Territory (Campbell & Beveridge 2009) to south-eastern Queensland.

Genus *Parachristianella* Dollfus, 1946*Parachristianella monomegacantha* Kruse, 1959
(Figs 43–45)

Material examined. Adult: 17 specimens, spiral valve, *Hemitygon fluviatorum*, Wynnum North (QM G235988–236004); 2 specimens, spiral valve, *Glaucostegus typus*, Wynnum North (QM G236016); 11 specimens, spiral valve, *Neotrygon trigonoides*, Wynnum North (QM G236008–15), Garden Island (QM G236005–7); Larval stage: 38 plerocerci, digestive gland, *Alpheus* spp. (*Al. richardsoni* and *Al. papillosus*), Dunwich (QM G236018–55).

Morphological features. Plerocerci: blastocyst divided into anterior and posterior parts; posterior section variable in shape, usually elongate, tapering, maximum length 0.80–1.20 (0.99, $n=7$), width 0.12–0.26 (0.18, $n=7$) (Fig. 43), osmoregulatory canals extend to posterior end; anterior part of blastocyst hemi-spherical, 0.43–0.81 (0.59, $n=10$) long, 0.23–0.47 (0.40, $n=10$) wide, without ridges, with numerous white circular plaques (Fig. 43); scolex length 0.93–1.11 (1.02, $n=10$), scolex width 0.13–0.16 (0.15, $n=10$), pars bothriialis 0.14–0.21 (0.16, $n=10$), pars vaginalis 0.49–0.61 (0.54, $n=10$), bulb length 0.41–0.55 (0.49, $n=10$), bulb width 0.04–0.05 (0.05, $n=10$). Four areas of dense red pigmentation at posterior end of pars vaginalis; pigment disappears when fixed.

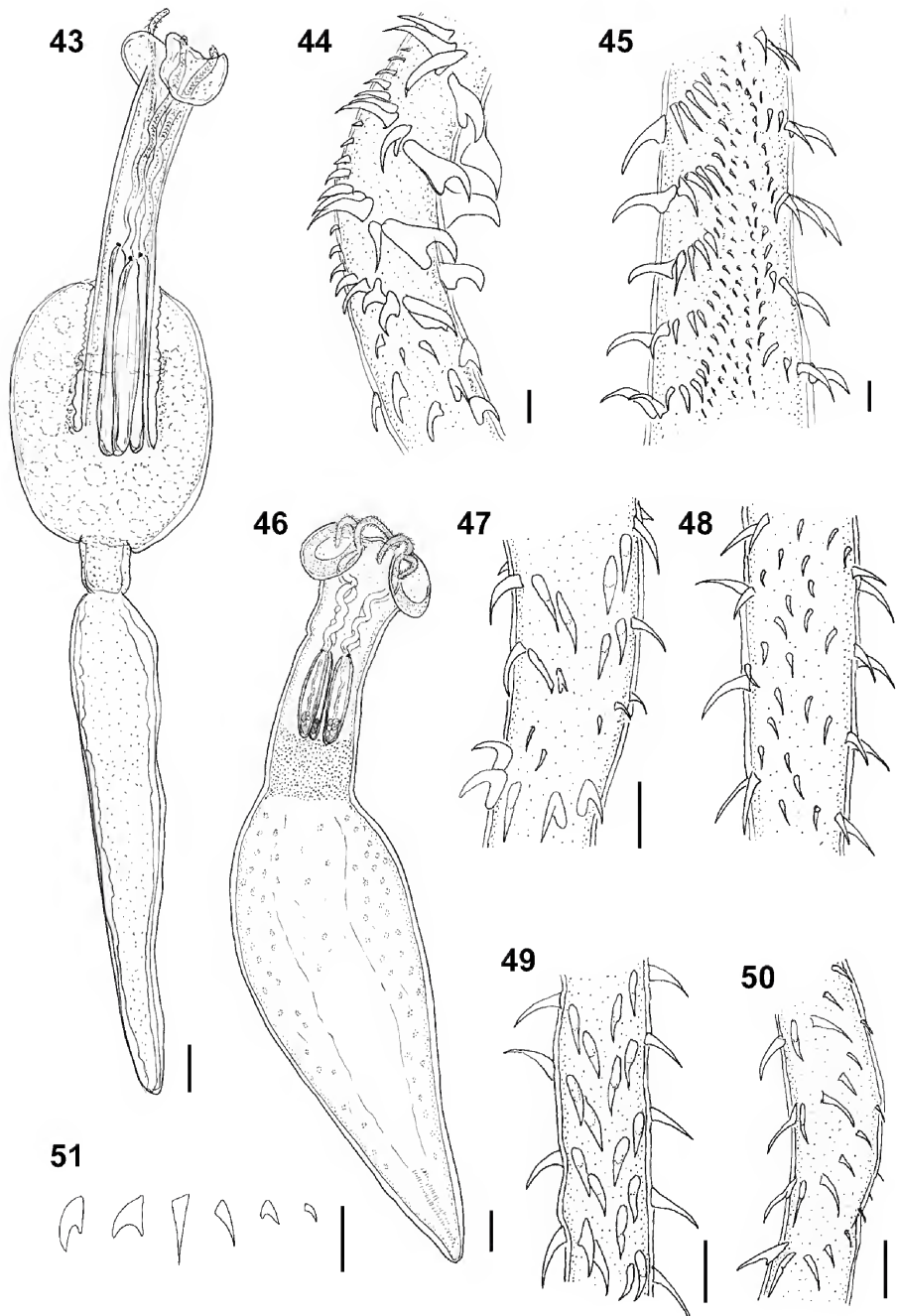
Tentacular armature. Basal tentacular swelling absent; basal armature consisting of 2 rows of uncinat hooks, not enlarged (Fig. 44); principal hook rows begin on internal surface, terminate on external surface (Fig. 45); hooks arranged in ascending rows; c. 16 hooks per row, decreasing in size along rows (Fig. 45); hooks 1(1') large, uncinat (Fig. 44); hooks 2(2') – 6(6') spiniform, gradually decreasing in size; remaining hooks tiny, spiniform; hooks solid.

Remarks. *Parachristianella monomegacantha* is a cosmopolitan species having been reported from a wide range of host species in the Gulf of Mexico (Kruse 1959), off the Atlantic coast of the USA (Whittaker *et al.* 1985), Hawaii (Carvajal *et al.* 1976), off the west coast of France and the Mediterranean (Beveridge *et al.* 2004) and Borneo (Schaeffner & Beveridge 2014) as well as from Australia (Beveridge 1990). The plerocercus

has previously been reported from the digestive glands of the penaeid shrimps *Farfantepenaeus aztecus* (Ives, 1891) (formerly *Penaeus aztecus*) and *Fa. duorarum* (Burkenroad, 1939) (formerly *Penaeus duorarum*) from the Gulf of Mexico (Kruse 1959), in *Fa. brasiliensis* (Latreille, 1817) (formerly *Penaeus brasiliensis*) from Mexico (Mudry & Dailey 1971; Feigenbaum 1975) and Florida (Feigenbaum & Cornuccio 1976) as well as from *Fenneropenaeus merguensis* (de Man, 1888) (formerly *Penaeus merguensis*) on Cape York Peninsula, Australia (Owens 1981). Mudry and Dailey (1971) experimentally infected the copepod *Tigriopus californicus* (Baker, 1912) and studied the development of the proceroid. The species is adequately described (see Beveridge 1990) and therefore morphological data presented here are confined to the plerocercus. This is the first report of the plerocercus of *Para. monomegacantha* from alpheid shrimps. In some of the shrimps examined with large numbers of plerocerci in their digestive glands, *Para. monomegacantha* was the predominant species present, but the number of *Para. monomegacantha* was determined only in 20 shrimps from Dunwich collected in July 2016. *Parachristianella monomegacantha* was found in 12 shrimps with between 1 and 61 (mean 23, $n=12$) individuals in each shrimp.

The description presented here agrees with earlier descriptions of the species (Kruse 1959; Beveridge 1990), but the observation of live material enabled the additional description of the red pigment at the posterior end of the pars vaginalis in both plerocerci and adults. Such pigment has been reported in a number of other eutetrarhynchoid species (Dollfus 1942, pp. 56–57). The plerocerci of this species were readily recognisable in the live state relative to other co-occurring species by the white circular plaques on the anterior region of the blastocyst (Fig. 43).

Parachristianella monomegacantha has been reported previously from Moreton Bay (Beveridge 1990) in *H. fluviatorum*. However, both *G. typus* and *N. trigonoides* represent new host records.



FIGS. 43-51. *Parachristianella monomegacantha* Kruse, 1959 (43-45) and *Parachristianella* sp. (undescribed) (46-51). 43, plerocercus, dorso-ventral view; 44, basal armature of plerocercus, internal surface on right; 45, plerocercus, metabasal armature, external surface. 46, plerocercus, lateral view; 47, basal armature, internal surface; 48, metabasal armature, external surface; 49, metabasal armature, internal surface; 50, metabasal armature, bothrial surface; 51, profiles of hooks 1-6. Scale bars: Figs 43, 46 = 0.1 mm; 44-45, 47-51 = 0.01 mm.

***Parachristianella* sp. nov.**
(Figs 46–51)

Material examined. 16 plerocerci, digestive gland, *Alpheus* sp., Wynnum (SAM 36328); 1 immature adult, spiral valve, *Hemitygon fluviolum*, Wynnum North (QM G236056).

Description. Plerocerci: scolex length 0.56–0.76 (0.69, n=10) (Fig. 46), scolex width 0.20–0.30 (0.24, n=10), pars bothrials 0.16–0.20 (0.19, n=10), pars vaginalis 0.21–0.38 (0.30, n=10), tentacle sheaths sinuous; bulb length 0.22–0.27 (0.25, n=10), bulb width 0.04–0.06 (0.05, n=10), bulb ratio 4.3–6.5 (5.3, n=10); prebulbar organ present; retractor muscle originates at base of bulb; gland cells present within bulb; pars post bulbosa 0.10–0.18 (0.13, n=10); blastocyst vermiform, tapering posteriorly (Fig. 46), 0.65–1.12 (0.92, n=10) long, 0.40–0.54 (0.46, n=10) wide; pygidium inapparent.

Tentacular armature. Tentacles without basal swelling and distinctive basal armature, 10–25 µm (17, n=10) in diameter. Armature heteroacanthous, heteromorphous; hooks solid; armature begins on internal surface (Figs 47, 49), ends on external surface (Fig. 48); hooks arranged in ascending half circles with 6 hooks per principal row (Fig. 50). Base with ring of uncinat hooks (Fig. 47), 7.0–9.0 µm (8.4, n=5) long, base 4.0–6.0 µm (5.0, n=5) long; ascending rows begin immediately after basal ring on internal surface; hooks 1(1') large, uncinat, 8.0–11.0 µm (9.8, n=5) long, base 4.0–6.0 µm (4.8, n=5) long; hooks 2(2') uncinat, 8.0–9.0 µm (8.2, n=5) long, base 4.0–6.0 µm (4.6, n=5) long; hooks 3(3') erect, spiniform, with short base, 10.0–11.0 µm (10.2, n=5) long, base 2.0–3.0 µm (2.2, n=5) long, hooks 4(4') short, spiniform, 4.0–7.0 µm (6.0, n=5) long, base 1.0–3.0 µm (1.8, n=5) long; hooks 5(5') short, spiniform, 4.0–6.0 µm (5.0, n=5) long, base 1.0–2.0 µm (1.2, n=5) long; hooks 6(6') short, spiniform, 3.0–5.0 µm (3.8, n=5), base 1.0 µm (1.0, n=5) long.

Remarks. Based on scolex lengths and bulb lengths, the species described above is closest to *Para. caribbensis* (Kovacs & Schmidt, 1980) (scolex length 0.64–0.75, bulb length 0.27–0.28) and *Para. parva* Campbell and Beveridge, 2007 (scolex length 0.33–0.42, bulb length 0.19–0.23) (Kovacs & Schmidt 1980; Campbell &

Beveridge 2007). However, the measurements of the species described here (scolex length 0.56–0.76, bulb length 0.22–0.27), do not match either of these species. The scolex tegument of *Para. caribbensis* is covered with enlarged microtriches (Kovacs & Schmidt 1980) which are lacking in the current species. *Parachristianella caribbensis* has 10 hooks in each principal row and *Para. parva* 11 hooks (Kovacs & Schmidt 1980; Campbell & Beveridge 2007), compared with only six hooks in the current species. Only a single adult specimen was found in a single *H. fluviolum*, but this specimen lacked segments. For these reasons, the current species is considered to be new but has not been named in the absence of mature adult specimens.

Genus *Poecilorrhynchus* Schaeffner & Beveridge, 2013

***Poecilorrhynchus perplexus* Schaeffner & Beveridge, 2013**

Material examined. 26 specimens, spiral valve, *Chiloscyllium punctatum*, Mud Island (QM G235304–29).

Remarks. This species was described recently from *Chiloscyllium punctatum* by Schaeffner and Beveridge (2013b) from the north west of Western Australia. The current record extends the distribution of this species to south-eastern Queensland. No additional morphological information was observable in the new specimens apart from the fact that in fresh specimens, there was a dense area of red pigmentation in the anterior extremity of the pars bulbosa.

Genus *Prochristianella* Dollfus, 1946

***Prochristianella aciculata* Beveridge & Justine, 2010**
(Figs 52–53)

Material examined. 1 specimen, spiral valve, *Neotrygon trigonoides*, Garden Island (QM G236061); 4 specimens, spiral valve, *Hemitygon fluviolum*, Wynnum North (QM G236509–60); 2 specimens, spiral valve, *Maculabatis cf. astra*, Garden Island (QM G236057–8); 47 plerocerci, digestive gland, *Alpheus* sp., Wynnum (SAM 36327, QM G236062–83); 1 plerocercus, digestive gland, *Trypaea australiensis*, Wynnum (QM G236084).

Morphological features. Plerocercus: blastocyst simple, variable in size, elongate (Fig. 52), 0.54 – 1.20 (0.79, n=10) long, 0.35–0.56 (0.41, n=10) wide, without ridges or white plaques; scolex without obvious pigments; scolex length 0.62–0.85 (0.75, n=10), scolex width 0.19–0.31 (0.27, n=10), pars bothriialis 0.16–0.26 (0.23, n=10), pars vaginalis 0.36–0.55 (0.43, n=10), bulb length 0.29–0.35 (0.32, n=10), bulb width 0.04–0.06 (0.05, n=10).

Remarks. This species was first described from *N. trigonoides* (as *N. kuhlii*) from New Caledonia (Beveridge & Justine 2010) and was subsequently reported from northern Australia (Nickol Bay, Western Australia and Weipa, Queensland) in *H. uarnak*, *M. toshi* and *Rhynchobatus* sp. (Schaeffner & Beveridge 2012). It is also common in elasmobranchs off Borneo (Schaeffner & Beveridge 2012, 2014). The records from *H. fluviatorum* and *M. cf. astra* presented here represent new host records.

The intermediate stage of this parasite has not previously been reported. *Prochristianella aciculata* was common in *Alpheus* spp. collected at Wynnum, but was absent at Dunwich, even though the two localities are only 4 km apart. A single specimen was recovered from the digestive glands of *T. australiensis* at Wynnum but not from the same host species at Dunwich.

The measurements of the scolex of the plerocerci agree well with those from the adults reported by Beveridge and Justine (2010) and the characteristic aciculate hooks of the metabasal armature are unique within the genus (Fig. 53).

Prochristianella butlerae Beveridge, 1990

Syn: *Prochristianella odonoghuei* Beveridge, 1990 (new synonymy). (Figs 54–58)

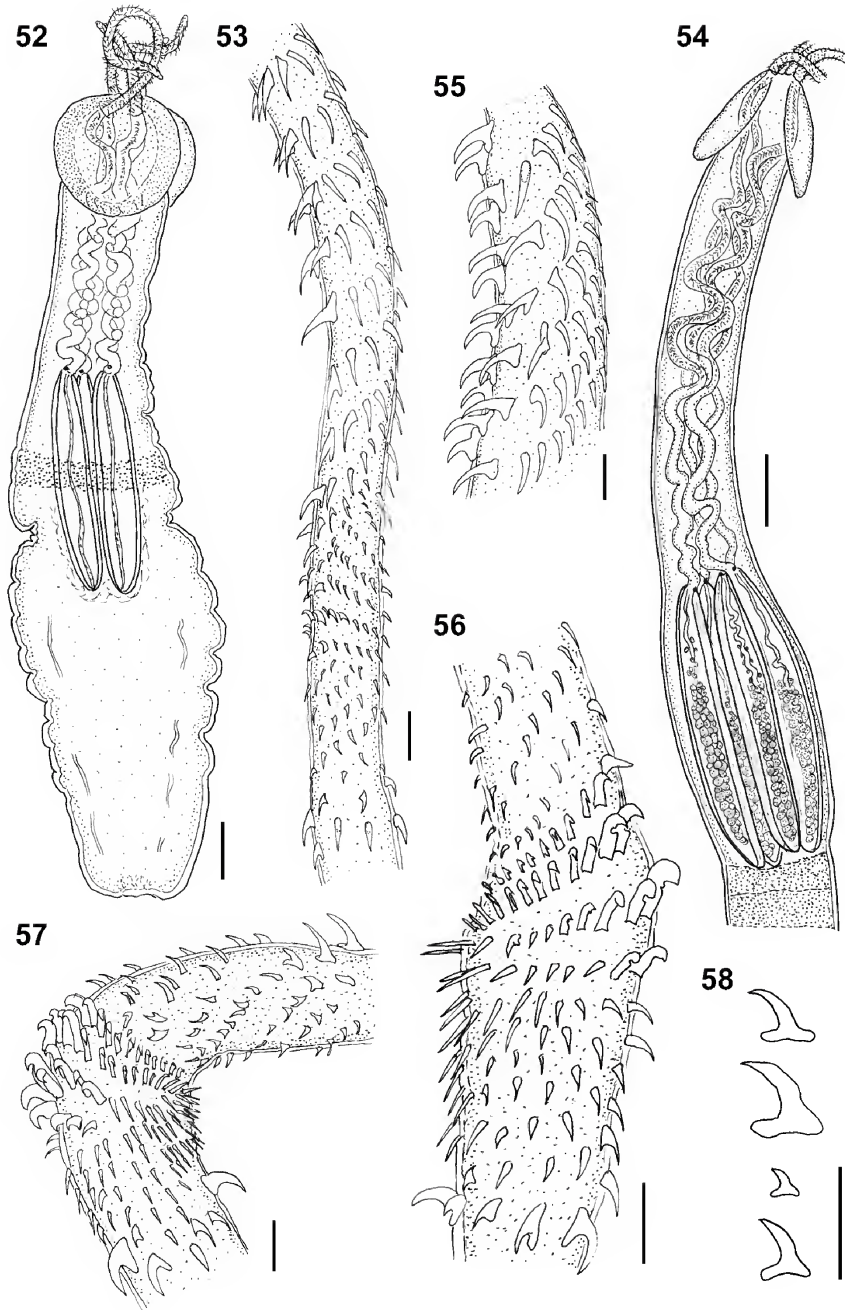
Material examined. 130 specimens, spiral valve, *Pastinachus ater*, Peel Island (QM G236085–119); 1 specimen, spiral valve, *Glaucostegus typus*, Wynnum North (QM 236120).

Morphological features. (Specimens from *P. ater*): scolex length 0.96–1.26 (1.09, n=10) (Fig. 54), scolex width in pars vaginalis 0.10–0.16 (0.14, n=10), in pars bulbosa 0.15–0.22 (0.19, n=10), pars bothriialis 0.16–0.19 (0.17, n=10), pars vaginalis 0.56–0.75 (0.63, n=10), bulb length 0.39–

0.49 (0.44, n=10), bulb width 0.06–0.07 (0.07, n=10), pars postbulbosa absent.

Remarks. *Prochristianella butlerae* was first described from *H. fluviatorum* from Moreton Bay, as well as from *P. ater* (as *Dasyatis sephen* Forsskal, 1775) from the Northern Territory and Western Australia (Beveridge 1990). Palm (2004) described the same species under the name *Prochristianella macracantha* Palm, 2004 from "*Pastinachus sephen*" (probably *P. ater* based on distributions in Last *et al.* (2010)) from Indonesia, and Haseli *et al.* (2010) reported the same species from *P. cf. sephen* from the Persian Gulf. Schaeffner and Beveridge (2012) reduced *Pro. macracantha* to synonymy with *Pro. butlerae*, while also noting variation within the species. Schaeffner and Beveridge (2012) reported the species from Borneo as well as from additional localities in Australia (Heron Island, Lizard Island and Weipa in Queensland) and expanded the host range to include species of *Aetomyleus* Garman, 1908, *Neotrygon* Castelnau, 1873, *Taeniura* Müller and Henle, 1837 and *Urogymnus* Müller and Henle, 1837 belonging to the Myliobatidae and Dasyatidae. *Prochristianella butlerae* appears to be one of the more widely distributed members of the genus. *Glaucostegus typus* is reported here as a new host for the species.

Prochristianella butlerae is very similar to *Pro. odonoghuei* Beveridge, 1990 and the two species have been reported from the same host, *P. ater* by Beveridge (1990). Beveridge (1990) did not discuss the separation of these two species, but relied on the differences in the sizes of the bill-hooks on the basal swelling of the tentacle. However, not only are the cardinal measurements of these two species very similar, but the hooks of the metabasal armature are also very similar. Hooks 1(1') are uncinatate with an enlarged base as are hooks 2(2') (Fig. 55). Subsequent hooks are uncinatate or spiniform, but the morphology of hooks 1(1') and 2(2') is quite characteristic and is similar in both species. Although the bill hooks on the basal armature of *Pro. odonoghuei* were reported to be larger than those of *Pro. butlerae* (0.016–0.018 versus 0.005–0.010) (Figs 56, 57), re-examination of the paratype specimens suggests that this may have been due to viewing the hooks in different



FIGS. 52-58. *Prochristianella aciculata* Beveridge and Justine, 2010 (52 - 53) and *Prochristianella butlerae* Beveridge, 1990 (54 - 58). 52, plerocercus, dorso-ventral view; 53, basal and metabasal armature, external surface; 54, scolex, lateral view; 55, metabasal armature, internal surface, antibothrial surface on left; 56, basal armature, oblique view of external surface, antibothrial surface on left; 57, basal armature, internal surface, antibothrial surface on right, showing prominence of bill hooks on bothrial surface; 58, profiles of hooks 1(1') and 2(2'). Scale bars: Figs 52, 54 = 0.1 mm; 53, 55-58 = 0.01 mm.

orientations. When the enlarged bill- hooks of the paratype specimens of *Pro. odonoghuei* (SAM 218313) and *Pro. butlerae* (SAM 218315) were drawn at the same orientation, they proved to be indistinguishable. Current data therefore suggest that the two species are synonyms.

***Prochristianella clarkeae* Beveridge, 1990**
(Figs 59-62)

Material examined. 4 specimens, spiral valve, *Hemitrygon fluviorum*, Wynnum North (QM G236180-2, G236188); 7 specimens, spiral valve, *Neotrygon trigonoides*, Garden Island (QM G236173-9); 1 specimen, Wynnum North (QM G236187); 3 specimens, spiral valve, *Maculabatis toshi*, Peel Island (QM G236171), Green Island (QM G236172), 2 specimens, Wellington Point (QM G236189-90); 49 specimens, spiral valve, *Maculabatis cf. astra* Garden Island (QM G236121-70); 7 specimens, spiral valve, *Glaucostegus typus*, Wynnum North (QM G236183-6, G236191-3); 1 specimen, Garden Island (QM G236194).

Morphological features. Measurements of specimens from *M. cf. astra*: Scolex length 0.58-0.75 (0.67, n=10) (Fig. 59), scolex width 0.10-0.14 (0.13), pars bothriialis 0.10-0.15 (0.13, n=10), pars vaginalis 0.26-0.41 (0.32), bulb length 0.30-0.37 (0.33), bulb width 0.03-0.05 (0.04, n=10), pars postbulbosa 0-0.02 (0.01, n=10).

Remarks. This species was described from a wide range of Australian elasmobranchs, including specimens from *N. trigonoides* (as *Amphotistius kuhlii*) from Moreton Bay (Beveridge 1990). Schaeffner and Beveridge (2012) reported extensive collections from Borneo as well as new collections from northern Australia, thereby expanding the host range to 43 elasmobranch species. Salmani and Haseli (2017) have reported the species from *P. sephen* from the Persian Gulf, together with molecular evidence for its identification. The current report potentially includes three new host species, *M. cf. astra*, *H. fluviorum* and *G. typus*. However, *M. cf. astra* was formerly confused with *M. toshi* (Last & Stevens 2009) and therefore it is possible that the original record of *Pro. clarkeae* from *M. toshi* in Beveridge (1990) could be from *M. astra*.

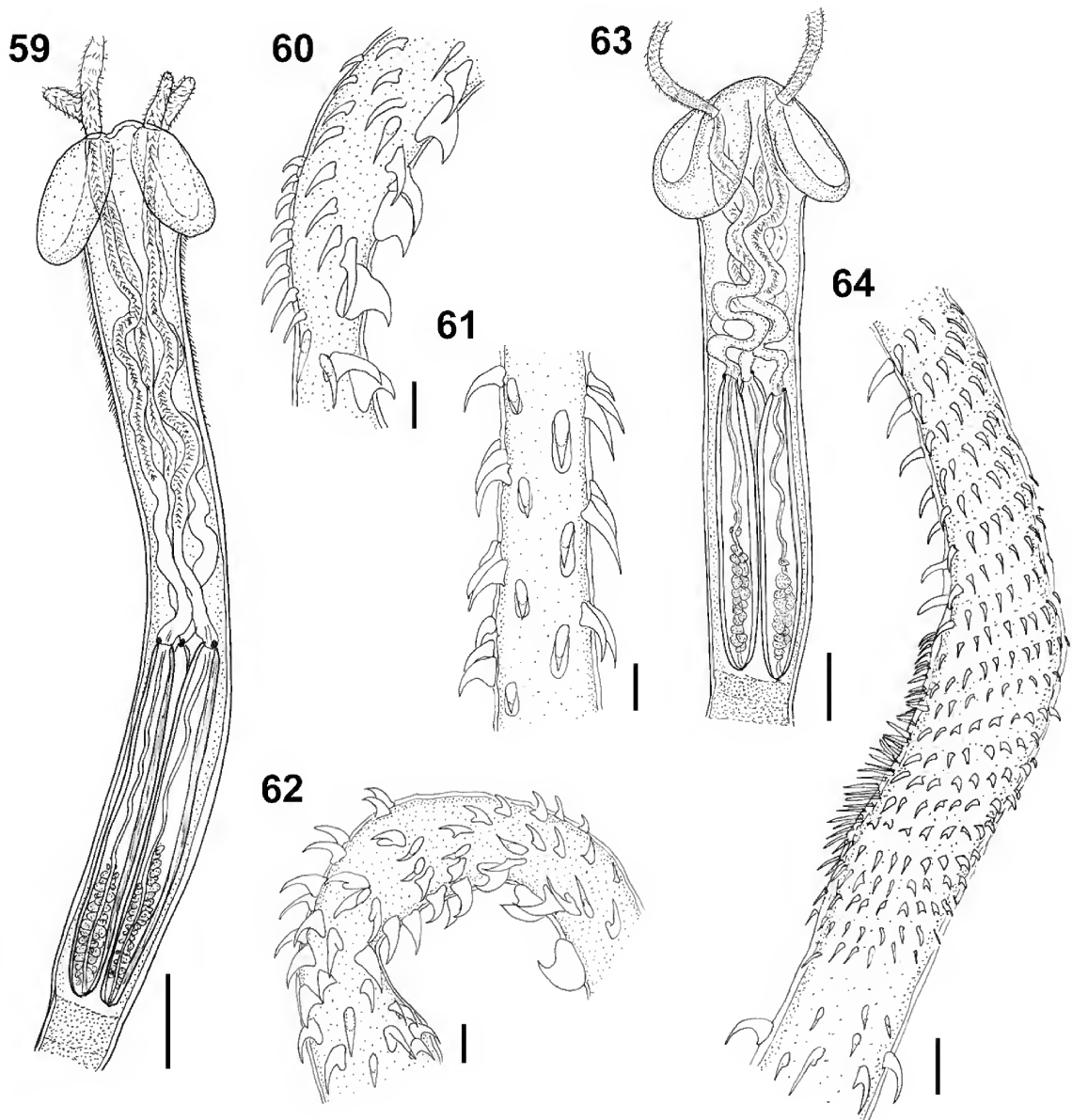
Schaeffner and Beveridge (2012) noted variation in the distribution of microtriches on the scolex, with some well-preserved specimens entirely

lacking enlarged microtriches and noting that in specimens from the South Australian Gulfs, enlarged microtriches were also entirely absent. Salmani and Haseli (2017) studied this variation in specimens from the Persian Gulf using scanning electron microscopy together with molecular identification of their specimens. They concluded that there was indeed intraspecific variation in the distribution of enlarged microtriches on the scolex, but that normally, the microtriches extended to the anterior region of the pars bulbosa. In the current series of specimens, microtriches generally extended to the level of the anterior region of the pars bulbosa, but three specimens in the series from *M. cf. astra* and one specimen in the series from *M. toshi* had microtriches extending as far as the mid pars vaginalis. In a single specimen from *M. toshi*, the microtriches extended to the posterior end of the scolex. However, the current study relied entirely on light microscopy and it is possible that microtriches were overlooked. Salmani and Haseli (2017) found in their study that microtriches not evident using light microscopy were seen using SEM. In this study, several specimens were mounted in Hoyer's medium which greatly facilitated the determination of enlarged microtrich distribution. However, too few specimens were mounted to allow broad conclusions to be drawn. The measurements of specimens presented here are much smaller, often 50% smaller than those of the original description (Beveridge 1990). Given the wide host and geographical distribution of this species, a more careful examination is warranted lest the current concept of the species be too broad and additional species are present under this current name.

In fresh specimens of this species, there was an area of red pigmentation at the anterior extremity of the pars bulbosa.

Prochristianella omunae
Beveridge & Justine, 2010
(Figs 63-64)

Material examined. 2 specimens, spiral valve, *Neotrygon trigonoides*, Wynnum North (QM G236195-6); 1 specimen, Wynnum (QM G236197); 1 specimen, Amity Point, Qld (QM G236198).



FIGS. 59-64. *Prochristianella clarkae* Beveridge, 1990 (59 - 62) and *Prochristianella omunae* Beveridge and Justine, 2010 (63 - 64). 59, scolex, lateral view; 60, metabasal armature, external surface; 61, metabasal armature, antibothrial surface; 62, basal armature, external surface; 63, scolex, lateral view; 64, basal and metabasal armature, external surface. Scale bars: Figs 59, 63 = 0.1 mm; 60-62, 64 = 0.01 mm.

Morphological features. Scolex length 0.96, 1.01 (Fig. 63), scolex width 0.17, 0.17, pars bothrialis 0.20, 0.21, pars vaginalis 0.46, 0.46, bulb length 0.48, 0.50, bulb width 0.06, 0.06.

Remarks. *Prochristianella omunae* was described from *N. trigonoides* (as *N. kuhlii*) from New Caledonia (Beveridge & Justine 2010). The current record is the first from Australian waters. The measurements presented here

accord reasonably well with the original description and the species is immediately identifiable by the characteristically elongate region of basal armature (Fig. 64).

**Genus *Zygorhynchus* Beveridge
& Campbell, 1988**

***Zygorhynchus elongatus* Beveridge &
Campbell, 1988**
(Figs 65-66)

Material examined. 1 specimen, spiral valve, *Hemitrygon fluviorum*, Wynnum North (QM G236217); 1 specimen, spiral valve, *Maculabatis cf astra*, Garden Island, (QM G236215-6).

Morphological features. Immature specimen from *H. fluviorum*: scolex length 6.8 (Fig. 66), pars bothrials 0.73, pars vaginalis 3.5, bulb length 2.9, bulb width 0.15, pars postbulbosa 0.05, tentacular diameter 0.10, hook length 0.025 (internal and external surfaces), hook base 0.025 (internal and external surfaces), 0.018 (bothrial and antiothrial surfaces); immature specimen from *M. cf. astra*: scolex length 6.3, pars bothrials 0.89, pars vaginalis 3.65, bulb length 3.25, bulb width 0.18, pars postbulbosa 0.09, tentacle diameter 0.10, hook length 0.025 (internal and external surfaces), 0.020 long (bothrial and antiothrial surfaces), hook base 0.020-0.025 long (internal and external surfaces), 0.018 (bothrial and antiothrial surfaces).

Remarks. Although both specimens were immature, their general features were consistent with those of *Z. elongatus*. Measurements were slightly larger than in the case of the original description of Beveridge and Campbell (1988b) but as the original and only description was based on six specimens, these differences are likely to be due to intraspecific variation. This species was originally described from *H. australis* (as *H. uarnak*), *M. toshi* and *Rhynchobatus djiddensis* (Forsskal, 1775) from the Northern Territory and the north-west of Western Australia (Beveridge & Campbell 1988b). The current hosts represent new records as well as indicating an expanded geographical distribution to include south-eastern Queensland. However, *M. astra* was not described until 2008 and this species had previously been included within *M. toshi* (Last

& Stevens 2009, p. 441). Consequently, a fish identified as *M. toshi* in 1988 from Nickol Bay, Western Australia, could have been *M. astra*.

***Zygorhynchus robertsoni* Beveridge &
Campbell, 1988**
(Figs 67-69)

Material examined. 1 adult specimen, spiral valve, *Maculabatis toshi*, Peel Island (QM G236220); 1 adult specimen, spiral valve, *Aetobatus ocellatus*, Peel Island (QM G236218-9); 1 plerocercus, digestive gland, *Alpheus papillosus*, Dunwich (QM G236221).

Morphological features. Immature specimen from *M. toshi*: scolex length 4.2, pars bothrials 0.81, pars vaginalis 2.4, bulb length 1.6, bulb width 0.21, pars postbulbosa 0.05; gravid specimen from *Ae. ocellatus*: scolex length 4.2, pars bothrials 0.79, pars vaginalis 2.7, bulb length 1.5, bulb width 0.29, pars postbulbosa absent; cirrus sac with internal seminal vesicle; distal vagina enlarged, with 2 diverticula; plerocercus: scolex length 4.7 (Fig. 67), pars vaginalis 2.8, bulb length 1.6, bulb width 0.24, pars postbulbosa 0.30. Hooks in basal region arranged in quincunxes (Fig. 69), slender, slightly sinuous, hook length 0.013-0.018 (0.015, n=10) with very short base, hook base 0.005-0.008 (0.006, n=10) long; metabasal hooks arranged in ascending rows, broad uncinated (Fig. 68), length 0.020-0.025 (0.022, n=10), with long base, 0.018-0.023 (0.021, n=10) long. Hooks hollow.

Remarks. The material examined consisted of an immature specimen (no strobila) from *M. toshi*, a gravid specimen from *Ae. ocellatus* and a plerocercus from *Al. papillatus*. The armature of the tentacles of the plerocercus (Figs 68-69) was identical to that already described for *Z. robertsoni* although the measurements of the scoleces were slightly different to those of the original description (Beveridge & Campbell 1988b), with a longer scolex, shorter pars bothrials, longer pars vaginalis and longer bulbs. However, the original description was based on only four specimens and the differences are considered to be due to intra-specific variation. The morphology of the mature and gravid segments conformed with the description of Beveridge and Campbell (1988b). One difference

noted relative to the original description was found in the metabasal armature. There, hooks are arranged in a heteroacanthous fashion (Fig. 68), whereas in the basal armature they are arranged in quincunxes (Fig. 69), therefore representing an homeoacanthous armature. This difference is not obvious in the illustration of Beveridge and Campbell (1988b, fig. 42), but is clear in the new material (Figs 68, 69). The original and only description of this species was from *H. australis* (as *H. uarnak*) and *N. leylandi* (as *Dasyatis leylandi*) from the Northern Territory (Beveridge & Campbell 1988b). As indicated above, the latter record is more likely to have been from *N. picta*. The current records are therefore from new host species and from a new geographic locality.

The plerocercus of this species has not been reported previously and provides novel information on the possible life cycle of the species. Only a single specimen was found in the 115 alpheid shrimps examined, although there may be additional crustacean intermediate hosts.

***Zygorhynchus* sp. nov.**
(Figs 70-71)

Material examined. 1 plerocercus, digestive gland, *Alpheus* sp., Dunwich (QM G236223); 1 immature cestode, spiral valve, *Neotrygon trigonoides*, Wynnum (QM G236222).

Description. Measurements of adult: scolex length 1.53; scolex width 0.30; pars bothriialis 0.31; pars vaginalis 0.85; bulb length 0.65; bulb width 0.09; bulb ratio 7.2; measurements of plerocercus: scolex length 1.50 (Fig. 70); scolex width 0.25; pars bothriialis 0.30; pars vaginalis 0.95; bulb length 0.67; bulb width 0.08; bulb ratio 8.4; blastocyst 0.56 long, 0.69 wide (Fig. 70). Two bothria, pars vaginalis longer than pars bothriialis; sheaths sinuous; bulbs elongate; prebulbar organ visible in adult, not in plerocercus; retractor muscle originates at base of bulb; gland cells present within posterior region of bulbs; bulbs project into pars postbulbosa. Tentacular armature: armature heteroacanthous, homeomorphous in metabasal region; hooks hollow; tentacle with basal swelling and distinctive basal armature (Fig. 71); basal swelling c. 30 μ m in diameter; hooks of basal armature erect, spiniform, 5-8

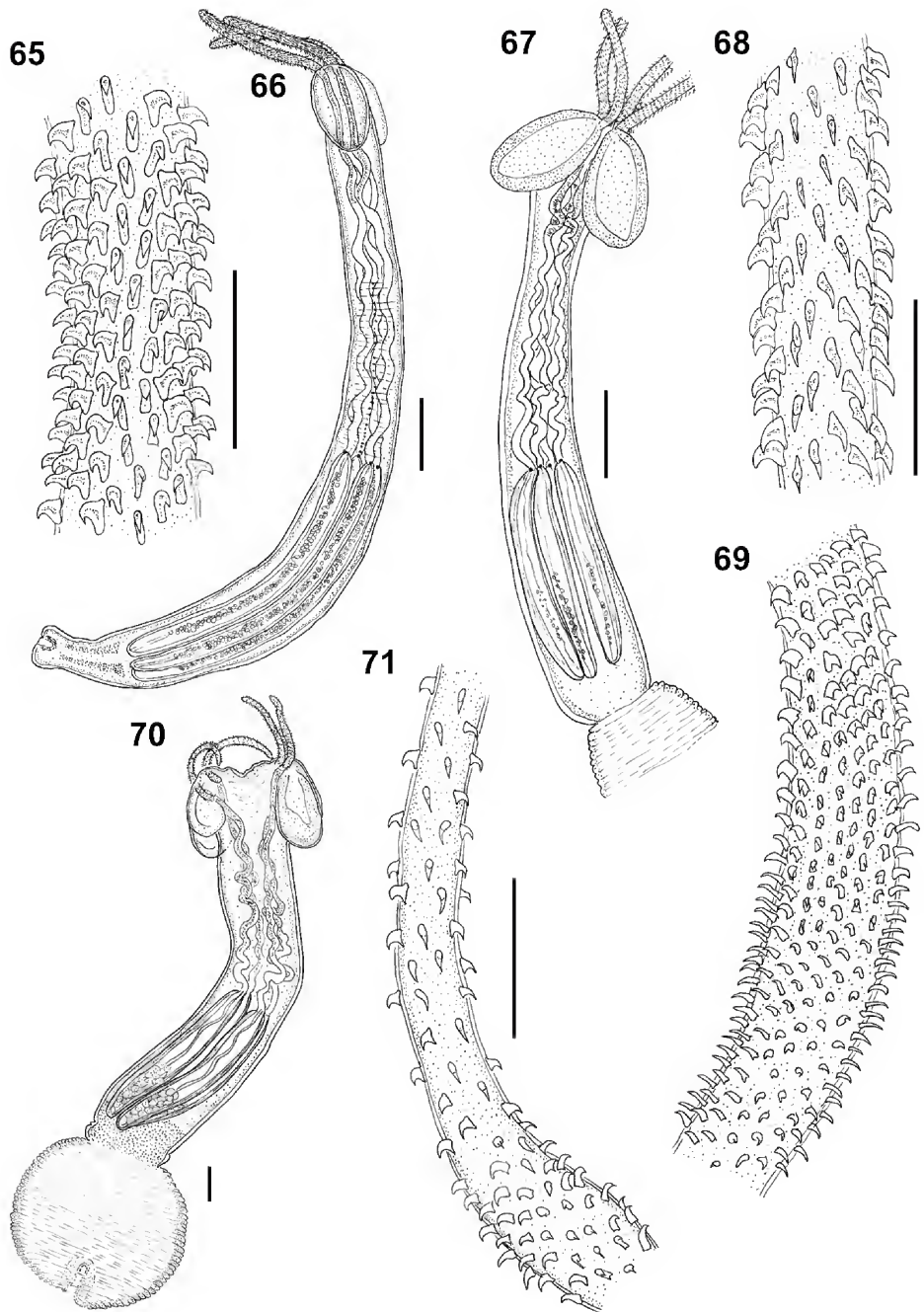
μ m (6.8, n=5) long, base 2-3 μ m (2.8, n=5) long; tentacle diameter in metabasal region c. 18 μ m; hooks of uniform size, arranged in ascending half circles of 5 hooks; hooks uncinuate with elongate base, 6-7 μ m (6.2, n=5) long, base 5-8 μ m (6.0, n=5) long. Adult unsegmented; plerocercus with ovoid blastocyst; blastocyst with prominent transverse folds; pygidium not prominent (Fig. 70).

Remarks. This species, which is represented only by a single plerocercus and a single immature adult is tentatively allocated to the genus *Zygorhynchus* based on its tentacular armature. Beveridge and Campbell (1988b) separated *Zygorhynchus* from *Tetrarhynchobothrium* Diesing, 1854 primarily on the morphology of the cirrus and distal vagina, features which are unknown in the current species. However, the tentacular armature is remarkably similar to that of *Z. robertsoni*, although all the measurements are much smaller. Consequently, these specimens appear to belong to an undescribed species of *Zygorhynchus*, but the material available is too limited to permit a formal description.

DISCUSSION

The two principal findings emerging from this study of the trypanorhynch fauna of Moreton Bay, along with a companion study of the species present as plerocerci and plerocercoids in teleosts (Beveridge *et al.* 2017a), are that the fauna is quite diverse and that the decapod families Callinassidae and Alpheidae are intermediate hosts for some of the cestode species using rays as definitive hosts.

The diversity of trypanorhynch cestodes reported here is not surprising given that collecting of these cestodes in the past has been entirely opportunistic. Two new species of *Dollfusella*, *D. armata* sp. nov. and *D. pilosa* sp. nov. were encountered. One species (*Pro. omunae*) is reported for the first time in Australia and a number of findings represent new host records (Table 3), new records for south-eastern Queensland and also significant extensions of the known geographical ranges of these species. The examination of a relatively wide range of species of rays has resulted in numerous new host records (Table 3), a



FIGS. 65-71. *Zygorhynchus elongatus* Beveridge and Campbell, 1988 (65-66), *Zygorhynchus robertsoni* Beveridge and Campbell, 1988 (67-69) (plerocercus) and *Zygorhynchus* sp. undescribed (70-71). 65, metabasal tentacular armature; 66, scolex, dorsoventral view; 67, scolex, lateral view; 68, metabasal tentacular armature; 69, basal tentacular armature; 70, plerocercus, lateral view; 71, basal and metabasal armature. Scale bars: Figs 65 - 70 = 0.1 mm; 71 = 0.01 mm.

result expected given the relatively low host specificity of many adult trypanorhynchs (Palm & Caira 2008). Schaeffner and Beveridge (2014) calculated specificity indices for *Para. monomegacantha*, *Pro. aciculata*, *Pro. butlerae* and *Pro. clarkeae* using the index developed by Caira *et al.* (2003), showing that each of these species was euryxenous. *Prochristianella clarkeae* had the highest index and widest host range of all the species they examined, with 41 known host species. By contrast, one of the new species described above, *D. pilosa*, was found in a single species of ray only, *Ae. ocellatus*, illustrating the range of host specificity seen in adult trypanorhynchs.

The results presented here suggest that more extensive collecting of elasmobranchs in Moreton Bay will reveal significant numbers of additional species. Unfortunately, there was inadequate material of several species available to permit a full description and hence these obviously new species have not been named. Recent keys to the genus *Dollfusiella* by Schaeffner and Beveridge (2013d) and Haseli and Palm (2015) utilise features of the mature segment, particularly testis number, as important differentiating features. Consequently, species have been named only in instances where some description of the pre-mature segments was possible. Naming of the remaining species encountered is dependent upon the collection of mature adult specimens.

Very few larval trypanorhynchs have been reported from callianassid and alpheid crustaceans (Dollfus 1929; Bates 1990; Palm 2004). Young (1954) reported a plerocercus identified as *Christianella trigonis-buccalis* (Wagener, 1854) from *Callianassa* sp. from southern California, with adults in *Urobatis halleri* (Cooper, 1863). Also cited as *Christianella trygonbrucce* (see Dollfus 1942, p. 219), this Mediterranean species was considered unrecognisable from its available descriptions by Beveridge *et al.* (2004) who suggested that it probably belonged within *Dollfusiella*. In addition, the only species of *Dollfusiella* reported to date from *U. halleri* is *Dollfusiella cortezensis* (Friggens & Duszynski 2005), redescribed by Menoret and Ivanov (2015). Consequently, the precise identity of Young's specimens remains uncertain. They do however

suggest the presence of a species of *Dollfusiella* in a callianassid.

Pearce (1934) reported the larval stage of a *Rhynchobothrius* sp. from "*Crangon armillatus* (Milne-Edwards, 1837)" collected in the Dry Tortugas, Florida. As *Rhynchobothrius* was used as a generic name for a wide variety of trypanorhynchs, its current generic allocation is uncertain. The current name of the shrimp host is *Alpheus armillatus* Milne-Edwards, 1837, as cited by Palm (2004). However, this species is currently considered to be a complex, with several species occurring in Florida (Anker 2012). The precise identity of the host and the parasite therefore remain to be determined. Dollfus (1942) cited the reference to this report as 'Pearce, 1932, p.107' but did not include the reference in his bibliography. The correct reference is Pearce (1934, p. 107). The title page indicates that the paper was issued in December 1932, but the volume was not published until September 1934. The publication date of the volume has been adopted here as no record of the 1932 issue could be found and it is cited in the Index Catalogue of Medical and Veterinary Zoology as having been published in 1934.

The present study therefore suggests that callianassids and alpheids may be significant intermediate hosts of eutrarhynchid cestodes. To date, most reports of crustacean hosts for eutetrarhynchids are from crabs and prawns, particularly commercial species (see records summarised in Dollfus 1942; Bates 1990; Palm 2004) with a very small number of additional records from holothurians and molluscs (Palm, 1994). In Australian waters, the plerocercus of *Para. monomegacantha* has been reported from prawns from the Gulf of Carpentaria (Owens 1981) and the plerocerci of *Dollfusiella martini* and *Trimacracanthus aetobatidis* (Robinson, 1959) have been reported from *Cancer maenas* Linnaeus, 1785 in Victoria (Gurney *et al.* 2004). Consequently, more detailed examination of callianassids and alpheids could prove to be fruitful. In this study only a limited number of crabs was examined for larval cestodes with no infections found, but more extensive sampling may reveal larval cestodes. In attempting to understand the life cycles of trypanorhynch

cestodes in Moreton Bay, a more extensive study of both crabs as well as prawns would be advisable.

ACKNOWLEDGEMENTS

This project was supported financially by the Australian Biological Resources Study National Taxonomy Research Grant RF215-40. We thank Tom Cribb and Scott Cutmore for providing the opportunities to collect all of the material included in this study, John Page and David Thompson for assistance with the collection of the elasmobranch hosts and Rod Bray, Storm Martin, Daniel Huston, Russell Yong, Xena Brooks, Nicholas Wee and Hoi Yan Iao for assistance with dissections. We thank Jeff Johnson of the Queensland Museum for assistance with fish identifications.

All applicable institutional, national and international guidelines for the care and use of animals were followed. Fish examined during this study were obtained from a commercial fishery.

We wish to thank Joan Clarke, Monash University, for taking the scanning electron micrographs.

LITERATURE CITED

Anker, A. 2012. Revision of the western Atlantic members of the *Alpheus armillatus* H. Milne Edwards, 1837 species complex (Decapoda, Alpheidae), with description of seven new species. *Zootaxa* **3386**: 1-109.

Banner, D.M. & Banner, A.H. 1982. The alpheid shrimps of Australia. Part III: The remaining alpheid, principally the genus *Alpheus*, and the family Ogyrididae. *Records of the Australian Museum* **34**: 1-357. <https://doi.org/10.3853/j.0067-1975.34.1982.434>

Bates, R.M. 1990. A checklist of the Trypanorhyncha (Platyhelminthes: Cestoda) of the world (1935-1985). *National Museum of Wales, Zoological Series* **1**: 1-218.

Beveridge, I. 1987. *Echinocephalus overstreeti* Deardorff & Ko, 1983 (Nematoda: Gnathostomatoidea) from elasmobranchs and molluscs in South Australia. *Transactions of the Royal Society of South Australia* **111**: 79-92.

Beveridge, I. 1990. Taxonomic revision of Australian Eutetrarhynchidae Guiart (Cestoda:

Trypanorhyncha). *Invertebrate Taxonomy* **4**: 785-845. <https://doi.org/10.1071/IT9900785>.

Beveridge, I., Bray, R.A., Cribb, T.C. & Justine, J.-L. 2014. Diversity of Trypanorhynch metacestodes in teleost fishes from coral reefs off eastern Australia and New Caledonia. *Parasite* **21**: 60 (pp. 19).

Beveridge, I. & Campbell, R.A. 1987. *Trimacracanthus* gen. nov. (Cestoda: Trypanorhyncha: Eutetrarhynchidae), with redescription of *T. acetabulatus* (Robinson, 1959) comb. nov. and *T. binuncus* (Linton, 1909) comb. nov. *Transactions of the Royal Society of South Australia* **111**: 163-171.

Beveridge, I. & Campbell, R.A. 1988a. *Cetorhinicola* n. g., *Shirleyrhynchus* n. g. and *Stragulatorhynchus* n. g., three new genera of trypanorhynch cestodes from elasmobranchs in Australian waters. *Systematic Parasitology* **12**: 47-60 <https://doi.org/10.1007/BF00182028>.

Beveridge, I. & Campbell, R.A. 1988b. A review of the Tetrarhynchobothriidae Dollfus, 1969 (Cestoda: Trypanorhyncha) with descriptions of two new genera, *Didymorhynchus* and *Zygorhynchus*. *Systematic Parasitology* **12**: 3-29 <https://doi.org/10.1007/BF00182025>.

Beveridge, I. & Campbell, R.A. 1996. New records and descriptions of trypanorhynch cestodes from Australian fishes. *Records of the South Australian Museum* **29**: 1-22.

Beveridge, I. & Campbell, R.A. 2001. *Proemotobothrium* n. g. (Cestoda: Trypanorhyncha), with the redescription of *P. linstowi* (Southwell, 1912) n. comb. and description of *P. southwelli* n. sp. *Systematic Parasitology* **48**: 223-233.

Beveridge, I., Cribb, T.H. & Cutmore, S.C. 2017a. Larval trypanorhynch cestodes in fishes from Moreton Bay, Queensland. *Marine and Freshwater Research* **68**: 2123-21. <https://doi.org/10.1071/MF17010>.

Beveridge, I., Haseli, M., Ivanov, V.A., Menoret, A. & Shaeffner, B.C. 2017b. Trypanorhyncha Diesling, 1863. *University of Kansas, Natural History Museum, Special Publication No.* **25**: 401-429.

Beveridge, I. & Jones, M.K. 2000. *Prochristianella spinulifera* n. sp. (Cestoda: Trypanorhyncha) from Australian dasyatid and rhynchobatid rays. *Systematic Parasitology* **47**: 1-8.

Beveridge, I. & Justine, J.-L. 2010. Two new species of *Prochristianella* Dollfus, 1946 (Platyhelminthes, Cestoda) from the blue-spotted stingray *Neotrygon kuhlii* (Müller & Henle, 1841) off New Caledonia. *Zoosystema* **32**: 643-652.

Beveridge, I., Neifar, L. & Euzet, L. 2004. Eutetrarhynchid cestodes from Atlantic and Mediterranean elasmobranchs, with the description of two new species of *Dollfusieila* Campbell & Beveridge, 1994 and redescription of *Prochristianella papillifer* (Poyarkoff, 1909) Dollfus, 1957 and *Parachristianella trygonis* Dollfus, 1946. *Systematic Parasitology* **59**: 81-102.

- Beveridge, I. & Sakanari, J.A. 1987. *Lacistorhynchus dollfusi* sp. nov. (Cestoda: Trypanorhyncha) in elasmobranch fishes from Australian and North American coastal waters. *Transactions of the Royal Society of South Australia* **111**: 147-154.
- Bush, A.O., Lafferty, K.D., Lotz, J.M. & Shostak, A. W. 1997. Parasitology meets ecology on its own terms: Margolis et al. revisited. *Journal of Parasitology* **83**: 575-583.
- Caira, J.N., Jensen, K. & Holsinger, K.E. 2003. On a new index of host specificity. In, (eds. C. Combes, J. Jourdan) *Taxonomy, ecology and evolution of metazoan parasites. Livre hommage à Louis Euzet*. (Presses Universitaires de Perpignan: Perpignan). Pp. 161-201.
- Campbell, R.A. & Beveridge, I. 1996. Revision of the family Pterobothriidae Pintner, 1931 (Cestoda: Trypanorhyncha). *Invertebrate Taxonomy* **10**: 617-662.
- Campbell, R.A. & Beveridge, I. 2007. A new species and new records of *Parachristianella Dollfus*, 1946 (Cestoda: Trypanorhyncha) from the Gulf of California, Mexico. *Comparative Parasitology* **74**: 218-228. <https://doi.org/10.1654/4261.1>
- Campbell, R.A. & Beveridge, I. 2009. *Oncomegas aetobatidis* sp. nov. (Cestoda: Trypanorhyncha), a re-description of *O. australiensis* Toth, Campbell & Schmidt, 1992 and new records of trypanorhynch cestodes from Australian hosts. *Transactions of the Royal Society of South Australia* **133**: 18-29.
- Carvajal, J., Campbell, R.A. & Cornford, I. 1976. Some trypanorhynch cestodes from Hawaiian fishes, with descriptions of four new species. *Journal of Parasitology* **62**: 70-77.
- Chervy, L. 2009. Unified terminology for cestode microtriches: a proposal from the International Workshop on Cestode Systematics in 2002-2008. *Folia Parasitologica* **56**: 199-230.
- Dollfus, R.P. 1929. Sur les Tétrarhynques. I. Définition des genres. *Bulletin de la Société Zoologique de France* **45**: 308-342.
- Dollfus, R.P. 1942. Etudes critiques sur les Tétrarhynques du Muséum de Paris. *Archives du Muséum national d'Histoire naturelle, Paris*, **19**: 1-466.
- Feigenbaum, D.L. 1975. Parasites of the commercial shrimps *Penaeus vannamei* Boone and *Penaeus brasiliensis* Latreille. *Bulletin of Marine Science* **25**: 491-514.
- Feigenbaum, D.L. & Cornuccio, J. 1976. Comparison between the trypanorhynch cestode infections of *Penaeus duorarum* and *Penaeus brasiliensis* in Biscayne Bay, Florida. *Journal of Invertebrate Pathology* **29**: 127-130.
- Friggens, M.M. & Duszynski, D.W. 2005. Four new cestode species from the spiral intestine of the round stingray, *Urobatis halleri*, in the northern Gulf of California, Mexico. *Comparative Parasitology* **72**: 136-149. <https://doi.org/10.1654/4121>
- Gurney, R.H., Nowak, B.F., Dykova, I. & Kuris, A.M. 2004. Histopathological effects of trypanorhynch metacestodes in the digestive gland of a novel host, *Carcina maenas* (Decapoda). *Diseases of Aquatic Organisms* **58**: 63-69.
- Haseli, M., Malek, M. & Palm, H.W. 2010. Trypanorhynch cestodes of elasmobranchs from the Persian Gulf. *Zootaxa* **2492**: 28-48.
- Haseli, M. & H. W. Palm. 2015. *Dollfusiella qeshmiensis* n. sp. (Cestoda: Trypanorhyncha) from the cowtail stingray *Pastinachus sephen* (Forsskal) in the Persian Gulf, with a key to the species of *Dollfusiella* Campbell & Beveridge, 1994. *Systematic Parasitology* **92**: 161-169.
- Kovacs, K.J. & Schmidt, G.D. 1980. Two new species of cestode (Trypanorhyncha: Eutetrarhynchidae) from the yellow-spotted stingray *Urolophus jamaicensis*. *Proceedings of the Helminthological Society of Washington* **47**: 10-14.
- Kruse, D.N. 1959. Parasites of the commercial shrimps, *Penaeus aztecus* Ives, *P. duorarum* Burkenroad and *P. setiferus* (Linnaeus). *Tulane Studies in Zoology* **7**: 123-144.
- Last, P.R. & Stevens, J.D. 1994. *Sharks and Rays of Australia. First edition*. (CSIRO Publishing: Melbourne). 513 pp.
- Last, P.R. & Stevens, J.D. 2009. *Sharks and Rays of Australia. Second edition*. (CSIRO Publishing: Melbourne). 644 pp.
- Last, P.R., White, W.T., Caira, J.N., Dharmadi, Fahmi, Jensen, K., Lim, A.P.K., Manjaji-Matsumoto, B.M., Naylor, G.J.P., Pogonoski, J.J., Stevens, J.D. & Yearsley, G.K. 2010. *Sharks and Rays of Borneo*. (CSIRO Publishing: Melbourne). 298 pp.
- Last, P.R., White, W.T., de Carvalho, M.R., Séret, B., Stehmann, M.F.W., & Naylor, G.J.P. 2016. *Rays of the World* (CSIRO Publishing: Melbourne). 790pp.
- Menoret, A. & Ivanov, V.A. 2015. Trypanorhynch cestodes (Eutetrarhynchidae) from batoids along the coast of Argentina, including the description of new species in *Dollfusiella* Campbell et Beveridge, 1994 and *Mecistobothrium* Heinz et Dailey, 1974. *Folia Parasitologica* **62**: 058.
- Mudry, D.R. & Dailey, M.D. 1971. Postembryonic development of certain tetraphyllidean and trypanorhynch cestodes with a possible alternative life cycle for the order Trypanorhyncha. *Canadian Journal of Zoology* **49**: 1249-1253.
- Naylor, G.J.P., Caira, J.N., Jensen, K., Rosana, K.A.M., White, W.T. & Last, P.R. 2012. A DNA sequence-based approach to the identification of shark and ray species and its implications

- for global elasmobranch diversity and parasitology. *Bulletin of the American Museum of Natural History* **367**: 1-262.
- Owens, L. 1981. Relationships between some environmental parameters and trypanorhynch cestode loads in banana prawns (*Penaeus merguensis* de Mann). *Australian Journal of Marine and Freshwater Research* **32**: 469-474.
- Palm, H.W. 2004. *The Trypanorhyncha* Diesing, 1863. (PKSPL-IPB Press: Bogor). 710 pp.
- Palm, H.W. & Beveridge, I. 2002. Tentaculariid cestodes of the order Trypanorhyncha (Platyhelminthes) from the Australian region. *Records of the South Australian Museum* **35**: 49-78.
- Palm, H.W. & Caira, J.N. 2008. Host specificity of adult versus larval cestodes of the elasmobranch tapeworm order Trypanorhyncha. *International Journal for Parasitology* **38**: 381-388.
- Pearce, A.S. 1934. Observations on the parasites and commensals found associated with crustaceans and fishes at Dry Tortugas, Florida. *Papers from the Tortugas Laboratory of the Carnegie Institute of Washington* **28**: 107-115 (publication number 435).
- Pintner, T. 1913. Vorarbeiten zu einer Monographie der Tetrarhynchoideen. *Sitzungsberichte der Kaiserlichen Akademie der Wissenschaften in Wien. Mathematik-Naturwissenschaftliche Classe* **122**: 171-253.
- Salmani, S. & Haseli, M. 2017. *Prochristianella clarkeae* Beveridge, 1990 (Eutetrarhynchidae): a species complex or a species with intraspecific variation in the distribution of its tegumental microtriches? *Acta Parasitologica* **62**: 69-75.
- Schaeffner, B.C. & Beveridge, I. 2012. *Prochristianella* Dollfus, 1946 (Trypanorhyncha: Eutetrarhynchidae) from elasmobranchs off Borneo and Australia, including new records and four new species. *Zootaxa* **3505**: 1-25.
- Schaeffner, B.C. & Beveridge, I. 2013a. *Pristiorhynchus palmi* n. g., n. sp. (Cestoda: Trypanorhyncha) from sawfishes (Pristidae) off Australia, with redescrptions and new records of six species of the Otobothrioidea Dollfus, 1942. *Systematic Parasitology* **84**: 97-121.
- Schaeffner, B.C. & Beveridge, I. 2013b. *Poecilorrhynchus perplexus* n. g., n. sp. (Cestoda: Trypanorhyncha) from the brownbanded bamboo shark *Chiloscyllium punctatum* Müller & Henle, from Australia. *Systematic Parasitology* **85**: 1-9.
- Schaeffner, B.C. & Beveridge, I. 2013c. *Dollfusiella* Campbell & Beveridge, 1994 (Trypanorhyncha: Eutetrarhynchidae) from elasmobranchs off Borneo, including descriptions of five new species. *Systematic Parasitology* **86**: 1-31.
- Schaeffner, B.C. & Beveridge, I. 2014. The trypanorhynch fauna of BorN. *Zootaxa* **3900**: 21-49.
- Toth, L.M., Campbell, R.A. & Schmidt, G.D. 1992. A revision of *Oncomegas* Dollfus, 1929 (Cestoda: Trypanorhyncha: Eutetrarhynchidae), the description of two new species and comments on its classification. *Systematic Parasitology* **22**: 167-187.
- Whittaker, F.H., Apkarian, A.P., Curless, B. & Carvajal, J. 1985. Scanning electron microscopy of the scolices (sic) of *Parachristianella monomegacantha* Kruse, 1959 (Trypanorhyncha) and *Phyllobothrium* sp. Beneden, 1849 (Tetraphyllidea). *Journal of Parasitology* **71**: 376-381.
- Young, R.T. 1954. Cestodes of sharks and rays in southern California. *Proceedings of the Helminthological Society of Washington* **21**: 106-112.

Three new species of acotylean polyclads (Platyhelminthes) from Queensland, Australia, with the erection of a new genus

Ian BEVERIDGE

Faculty of Veterinary and Agricultural Sciences, University of Melbourne, Veterinary Clinical Centre, Werribee 3030, Victoria, Australia. Email: ibeve@unimelb.edu.au

Citation: Beveridge, I. 2018. Three new species of acotylean polyclads (Platyhelminthes) from Queensland, Australia, with the erection of a new genus. *Memoirs of the Queensland Museum – Nature* 61:143-153. Brisbane. ISSN 2204-1478 (Online) ISSN 0070-8835 (Print). Accepted 5 June 2018 First published online 22 November 2018.

<https://doi.org/10.17082/j.2204-1478.61.2018.2017-12>

LSID: urn:lsid:zoobank.org:pub:F2C7A194-0E15-44D2-B891-8A6A4046CB86

ABSTRACT

Three new acotylean polyclads are described from the littoral zone in Queensland. *Amyris bulbosa* sp. nov. (Notoplanidae Faubel, 1983) is distinguished from congeners in possessing a prominent vagina bulbosa. *Emprosthopharynx heroniensis* sp. nov. (Stylochoplanidae Faubel, 1983) differs from related species in lacking sub-marginal eyes and tentacles, in the anterior position of the cerebral eyes, and possessing few ruffles in the pharynx and uterine vesicles. *Zygantrella queenslandensis* gen. nov., sp. nov. is erected as a monotypic genus within the Ilyplanidae Faubel, 1983 differing from confamilial genera in lacking a prostate but possessing a common gonopore and a penis stylet. □ new genera, new species, Polycladida, Platyhelminthes.

Compared with other regions of Australia, the polyclad fauna of the coasts of Queensland has arguably been better studied, with particular emphasis in recent publications being devoted to the highly diverse and colourful cotylean fauna found on the Great Barrier Reef (Newman & Cannon 1994a, b, 1997a, 2002). Nevertheless, given the likely high diversity of the polyclad fauna of the region, it is clear that many species remain to be described, particularly the less colourful representatives of the littoral acotylean fauna, for which there are relatively few recent reports (Beveridge 2000; Beveridge & Cribb 2000; Jennings & Newman 1996a, b; Newman & Cannon 1997b). The current report includes the description of three new species of acotylean polyclads from the littoral zone of the coasts of Queensland.

MATERIALS AND METHODS

Polyclads were collected from under rocks at low tide and were fixed following the method of Newman and Cannon (1995) in which worms were coaxed onto filter paper in seawater and then placed on a block of frozen 10% formalin in seawater and left for 24 hours to harden. Polyclads were photographed immediately following fixation and photographs have been deposited with the type specimens. Specimens were then transferred to 70% ethanol for storage. For examination, specimens were dehydrated in an ethanol series, cleared in methyl salicylate and mounted on slides in Canada balsam. The genital regions of representative specimens were excised using a scalpel blade, embedded in wax and serial sections cut at a thickness of 5 µm. Sections were stained with haematoxylin and eosin. Drawings were made using a drawing tube attached to an Olympus BH2

microscope. Measurements were made using an ocular micrometer and are presented in millimetres as the range followed by the mean and the number of specimens measured in parentheses. All specimens have been deposited in the Queensland Museum, Brisbane (QM) including colour images (Kodachrome slides) of each species.

Two differing taxonomic systems for the classification of the Polycladida are currently available, that of Faubel (1983) based primarily on the structure and position of the prostatic vesicle, following Bock (1913) and that of Prudhoe (1985) based primarily on the types and distribution of eyes, following Poche (1926). In considering the taxonomic position of each of the species described herein, their position in both taxonomic systems is discussed as following the two differing taxonomic systems can lead to differing results.

SYSTEMATICS

Sub-order ACOTYLEA Lang, 1884

Family NOTOPLANIDAE
(Marcus, 1947 sub-family) Faubel, 1983

Genus *Amyris* Marcus & Marcus, 1968

Amyris bulbosa sp. nov.
(Figs 1-5, 17, 18)

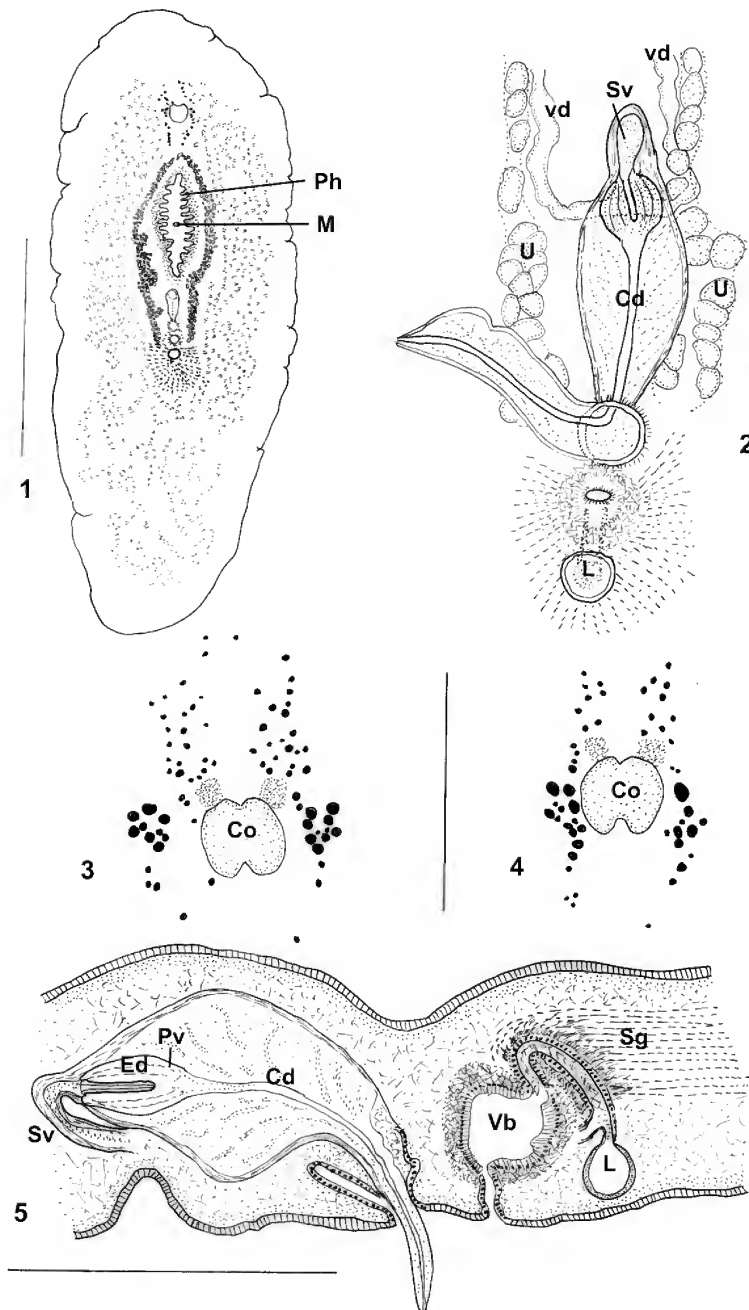
Material examined. Holotype, inter-tidal, under rocks, Rowe's Bay, Queensland (19° 16'S, 146° 49'E), coll. 1.vii.1994, whole mount (QM G235805); paratypes: 1 specimen, whole mount, same collection data (QM G235806); 1 specimen, whole mount, coll. 28.vi.1995 (QM G235807); 1 specimen, coll. 28.vi.1995, 17 serial sections and fragments as whole mount (QM G235809). Vouchers: 1 specimen, whole mount, Bowen, Qld, coll. 15.vi.1997 (QM G235810).

Description. Elongate polyclads (Fig.1), tapering posteriorly, 11–19 long, 3–7 wide; immature specimen 11 long, 3 wide; specimen with eggs just beginning to appear in uteri 15 long, 4 wide; fully gravid specimen with involution of male genitalia 19 long, 7 wide; dorsal surface light fawn in colour with darker brown speckles; speckles concentrated to either side of midline,

not extending to body margin. Tentacles lacking. Marginal eyes lacking; cerebral eyes present, c. 60 in number arranged in 2 elongate groups; divisible in some specimens into larger tentacular eyes, arranged in 2 clusters either side of cerebral organ, distinct from cerebral eyes (Fig. 3); otherwise, larger eyes forming part of continuous band with cerebral eyes (Fig. 4). Cerebral organ bilobed in dorso-ventral view, 0.32–0.40 (0.36, n=4) × 0.29–0.34 (0.32, n=4), 1.9–4.0 (2.4, n=4) from anterior margin. Pharynx situated in anterior half of body, immediately posterior to cerebral organ; pharynx 1.85–3.95 (3.00, n=4) long, plicate with c. 12 ruffles on either side; mouth in middle of pharynx; intestinal branches divaricate, non-anastomosing.

Male gonopore 1.1–1.9 (1.5, n=2) posterior to pharynx; unarmed cirrus elongate, projecting through gonopore in each specimen (Fig. 2); large sac with thin muscular walls 0.70–0.92 (0.81, n=2) long by 0.48–0.55 (0.52, n=2) wide, encloses prostatic vesicle and duct of cirrus, with skeins of muscle fibres running from duct to internal wall of sac (Figs 5, 17). Prostatic vesicle ovoid, 0.20–0.25 (0.23, n=2) long, 0.20 (n=2) wide (Fig. 5); ejaculatory duct projects into prostatic vesicle; interior of prostate divided into longitudinal chambers; prominent muscular seminal vesicle, 0.25–0.35 (0.30, n=2) long, 0.16–0.20 (0.18, n=2) in dorso-ventral view, runs ventrally and posteriorly from prostatic vesicle, giving rise to paired lateral vasa deferentia which run initially laterally then anteriorly (Fig. 2).

Female gonopore immediately posterior to that of male; female atrium leads to spherical vagina bulbosa, 0.37–0.44 (0.40, n=3) in diameter; wall of vagina bulbosa very thick, muscular (Figs 5, 18); epithelium composed of elongate cells with basal nuclei and foamy, faintly eosinophilic distal cytoplasm; shell duct arises from dorsal pole of vagina bulbosa, runs posteriorly and then ventrally to origin of uterine canals; shell duct with thick muscular wall, ciliated internally; surrounded by cement (or shell) glands; uterine canals run laterally and ventrally, apposed anterior to pharynx; duct of Lang's vesicle short; Lang's vesicle diminutive,



FIGS. 1-5: *Amyris bulbosa* sp. nov. 1, entire polyclad; 2, ventral view of terminal genitalia; 3, cerebral organ and eyes showing distinct clusters of tentacular eyes; 4, cerebral organ with tentacular eyes merged with cerebral eyes; 5, longitudinal section through terminal genitalia. Scale bars: Fig. 1, 10 mm; Figs. 2-5, 1 mm. Legend: Cd, duct of cirrus; Co, cerebral organ; Ed, ejaculatory duct; L, Lang's vesicle; M, mouth; Ph, pharynx; Pv, prostatic vesicle; Sg, shell glands; Sv, seminal vesicle; U, uterus; Vb, vagina bulbosa; vd, vas deferens.

spherical, 0.13–1.16 (0.15, $n=4$) in diameter. Cement or shell glands radiate posteriorly and postero-laterally from shell duct.

Remarks. Using the taxonomic system of Prudhoe (1985), the species described above belongs in the Gnesiocerotidae Marcus & Marcus, 1966 due to the lack of marginal eyes, the presence of a cirrus and the interpolated prostatic organ. The lack of tentacles, the presence of a seminal receptacle and the smooth cirrus, place the species in the genus *Amyris* Marcus & Marcus, 1968.

The taxonomic system of Faubel (1983) places the species in the Notoplanidae Faubel, 1983 and the presence of a cirrus, of Lang's vesicle and single male copulatory organ also place the species in the genus *Amyris*. Thus whichever taxonomic system is followed, the species belongs to *Amyris* although allocated to two different families by Prudhoe (1985) and Faubel (1983).

Three species are currently recognised within the genus: *A. hummelincki* (Marcus & Marcus, 1968), *A. favis* (Sopott-Ehlers & Schmidt, 1975) and *A. ujara* (Marcus & Marcus, 1968). The species described herein is distinguishable from the known species in being less slender and having the pharynx in the anterior rather than the posterior part of the body, as well as having many more ruffles (c. 12 in the current species) based on illustrations in Marcus and Marcus (1968) and, Sopott-Ehlers and Schmidt (1975). It differs from *A. hummelincki* and *A. ujara* in having a much smaller seminal vesicle and thinner wall to the cirrus sac. *Amyris hummelincki* possesses a simple vagina in contrast to the vagina bulbosa present in the current species. In *A. ujara*, Marcus and Marcus (1968) described the "outer" part of the vagina as "wide and folded", although their illustration (Fig. 55) suggests the presence of a cavity. They did not describe the histological features of the vagina and it is possible that a vagina bulbosa is present in this species. Sopott-Ehlers and Schmidt (1975) describe the female antrum of *A. favis* as being muscular and illustrate it as a cavity with thick walls and a thick epithelial lining, similar to the structure termed a vagina bulbosa seen in the current

species. In the current species, a distinct, rather elongate antrum is present and is distinct from the vagina bulbosa. However it seems that the vagina bulbosa in the current species and the antrum as described in *A. favis* are homologous structures. Lang's vesicle in *A. favis* is much larger than in the current species.

The male system is characterised by an unarmed cirrus that projects externally in all specimens examined although additional specimens are needed to determine that it is indeed retractable. Histologically, the outer wall of the everted cirrus is a hyaline-like membrane with a single layer of tiny flattened nuclei, but lacks any sign of an epithelium which would be the case if it were an everted penis.

The species described here therefore differs from all known species and a new species has been erected to accommodate it.

Family STYLOCHOPLANIDAE Faubel, 1983

Genus *Emprostopharynx* Bock, 1913

Emprostopharynx heroniensis sp. nov.
(Figs 6–10, 19)

Material examined. holotype from shell of hermit crab, reef flat, Heron Island, Queensland (23° 26'S 151° 55'E), whole mount (QM G235811); paratype, same collection data, whole mount and 9 serial sections (QM G235812–13).

Description. (Measurements given are from the holotype). Elongate polyclads, rounded anteriorly, tapering posteriorly, 22 long, maximum width 8 (Fig. 6); pale orange in colour but appearing slightly speckled due to anastomosing intestinal branches; lacking marginal or sub-marginal eyes; lacking tentacles but with tentacular eye clusters (Fig. 7) or elongate arrays (Fig. 8) of c. 10–12 large eyes on either side of cerebral organ; cerebral eyes smaller, arranged in 2 linear arrays anterior to cerebral organ, 5–8 eyes in each array diminishing in size anteriorly; cerebral organ bilobed, 0.36 long, 0.41 wide, 2.9 from anterior extremity. Pharynx elongate, 5.0 posterior to cerebral organ, 3.5 long, without ruffles (paratype) or with single ruffle (holotype); mouth opening in middle of

pharynx; intestinal branches with numerous anastomoses. Gonopores separate (Fig. 9); male gonopore 3.5 posterior to pharynx; penis papilla conical, prominent, filling male antrum; penis unarmed, leads dorsally and anteriorly to interpolated prostatic vesicle (Figs 10, 19), 0.41 long, 0.15 wide, with thick muscular wall and smooth internal lining of elongate eosinophilic cells; anterior pole of prostatic vesicle leads into ventrally reflexed muscular seminal vesicle, 0.15 long, 0.12 wide, from which thin-walled, convoluted, paired vasa deferentia run laterally and then anteriorly. Female gonopore 0.35 posterior to that of male, 5.2 from posterior end. Vagina with thick muscular wall and ciliated lining extends dorsally with a ventrally recurrent arm (Figs 10, 19), dividing into uterine canals almost at level of female gonopore; uterine canals run anteriorly, each with prominent, small diverticulum or uterine vesicle at level of seminal vesicle; neither holotype nor paratype ovigerous. Lang's vesicle absent; shell glands not evident.

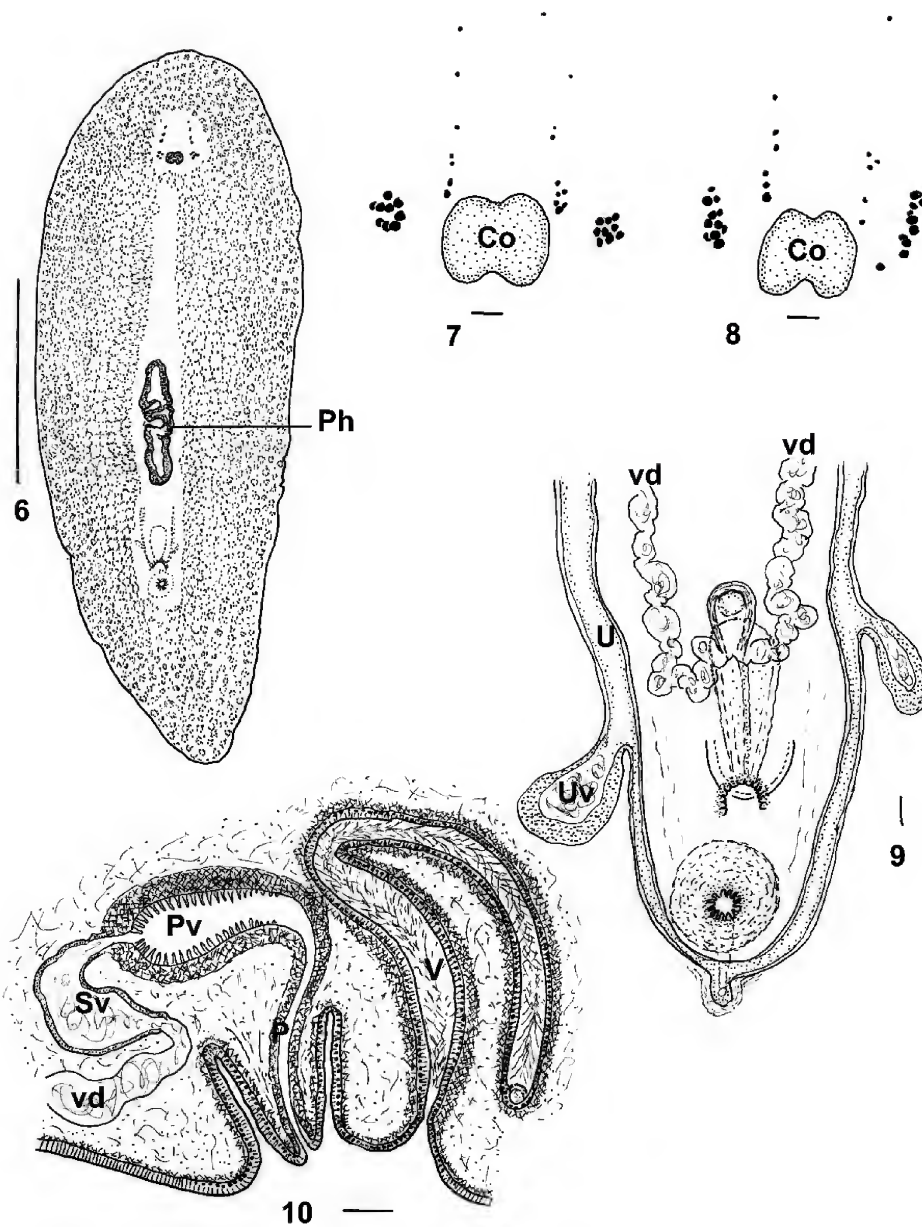
Remarks. Using the system of Faubel (1983), this species belongs within *Emprosthopharynx* Bock, 1913. The interpolated prostatic vesicle places it in the Schematommatidea Bock, 1913, the smooth lining of the prostatic vesicle, ruffled pharynx, lack of the ejaculatory duct projecting in to the prostatic organ, the lack of prostatic vesicles and the presence of true uteri place the species in the Stylochoplanidae (see Faubel 1983, p. 81). Within this family, the lack of a common gonopore, a papillate penis and the lack of Lang's vesicle place the species within *Emprosthopharynx* (see Faubel 1983, p. 100). By contrast, using the taxonomic system of Prudhoe (1985), the species belongs to the Planocercoidae Poche, 1926 and the family Leptoplanidae (see Prudhoe 1985, p. 81). Within this family, the muscular prostatic organ places the species within the Stylochoplaninae, and the various features identified in the key to genera by Prudhoe (1985) lead to the genera *Candibia* and *Stylochoplana*. The lack in the current species of Lang's vesicle, places the species in *Stylochoplana* and the separation of cerebral and tentacular eyes together with the

absence of a penis stylet places the species in Group A of Prudhoe (1985).

In the system of Faubel (1983, p. 100), *Stylochoplana* and *Emprosthopharynx* are related genera, differentiated primarily by the presence of Lang's vesicle in the former genus. In the system of Prudhoe (1985), sub-marginal eyes are present in *Emprosthopharynx* while in the system of Faubel (1983), sub-marginal eyes may or may not be present within the genus. Prudhoe (1985) considered that Lang's vesicle may be present or absent in *Stylochoplana*.

The species composition of the genus *Emprosthorrhynchus* adopted by Faubel (1983) and Prudhoe (1985) overlaps considerably and therefore species from both systems have been considered in identifying the species described here. Prudhoe (1985) accepted *E. opisthoporus* Bock, 1913 (type species), *E. rasae* Prudhoe, 1968 and *E. vanhoeffeni* Bock, 1913, while Faubel (1983) accepted these three species but also included *E. hancocki* (Hyman, 1953) (formerly *Stylochoplana hancocki* Hyman, 1953) and *E. pallidus* (Quatrefages, 1845) (formerly *Polycelis pallidus* Quatrefages, 1854). The species described here is immediately differentiable from the three species admitted to the genus by Prudhoe (1985) in lacking sub-marginal eyes and differs from *E. hancocki* in lacking tentacles, in having the cerebral eyes distributed exclusively anterior to the cerebral organ (both anterior and posterior to it in *E. hancocki*) and having few or no ruffles to the pharynx, compared with numerous folds in *E. hancocki*, based on the original description by Hyman (1953). *Emprosthopharynx pallidus* is greenish in colour (Quatrefages 1845, p.133) (compared with pale orange in the present species), the prostatic vesicle is well anterior to the seminal vesicle and is linked to it by a narrow duct (Quatrefages 1845, Plate 8, fig 2) while in the current species, the seminal vesicle opens directly into the prostatic vesicle, and it apparently lacks uterine vesicles, which are present in the current species.

Prudhoe's (1985) *Stylochoplana* Group A includes: *S. aberrans* (Kato, 1944), *S. agilis* (Lang, 1884), *S. alcha* (du Bois-Reymond & Marcus,



FIGS. 6–10. *Emprostopharynx heroniensis* sp. nov. 6, entire polyclad, holotype; 7, 8, cerebral organ and eyes, showing variation in shapes of tentacular eye clusters (7, holotype; 8, paratype); 9, terminal genitalia, ventral view; 10, longitudinal section through terminal genitalia. (Scale bars: Fig. 6, 5 mm; Figs. 7–10, 0.1 mm). Legend: Co, cerebral organ; P, penis; Ph, pharynx; Pv, prostatic vesicle; Sv, seminal vesicle; U, uterus; Uv, uterine vesicle; V, vagina; vd, vas deferens.

1968), *S. amica* Kato, 1937, *S. challengerii* (Graff, 1892), *S. conoceraea* (Schmarda, 1859), *S. gracilis* (Heath & McGregor, 1913), *S. graffii* (Laidlaw, 1906), *S. lynca* (du Bois-Reymond & Marcus, 1958), *S. maculata* (Quatrefages, 1845), *S. nadiiae* (Melouk, 1941), *S. palmula* (Quatrefages, 1845), *S. parasitica* (Kato, 1935), *S. pusilla* (Bock, 1924), *S. selenopsis* (Marcus, 1947), *S. tarda* (Graff, 1878) and *S. utonomii* (Kato, 1943). All of these species apart from *S. gracilis* possess a Lang's vesicle and are therefore differentiable from the species described here. *Stylochoplana gracilis* was transferred to *Emprostopharynx* by Faubel (1983).

The genus *Emprostopharynx*, as defined by Faubel (1983) therefore includes two groups of species clearly defined by the presence or absence of sub-marginal eyes. The type species, *E. opisthorus* possesses sub-marginal eyes, as do *E. rasae* and *E. vanhoeffeni*, while *E. pallida*, *E. gracilis*, *E. hancocki* and the new species lack them. Faubel (1983) pointed out the inconsistencies of using eye distribution in family level classifications, preferring to base his classification primarily on features of the male reproductive system. He considered eye patterns useful at the species level, following the lengthy historical usage of these characters, but did not consider their use at a generic level. It seems appropriate in this instance to indicate that the species allocated to *Emprostopharynx* by Faubel (1983) appear to represent two genera differentiated by the distribution of eyes and the erection of a new genus may be warranted in the future,

Prudhoe (1985, p. 120) noted that species of *Emprostopharynx* tend to be associated with hermit crabs, as is the case with the new species described here.

Family ILYPLANIDAE Faubel, 1983

Genus *Zygantrella* gen. nov.

Diagnosis. Ilyplanidae, of oval body form; cerebral tentacles present; eyes in paired cerebral and tentacular clusters, marginal eyes absent; pharynx plicate, oriented antero-posteriorly; common genital pore located posterior to

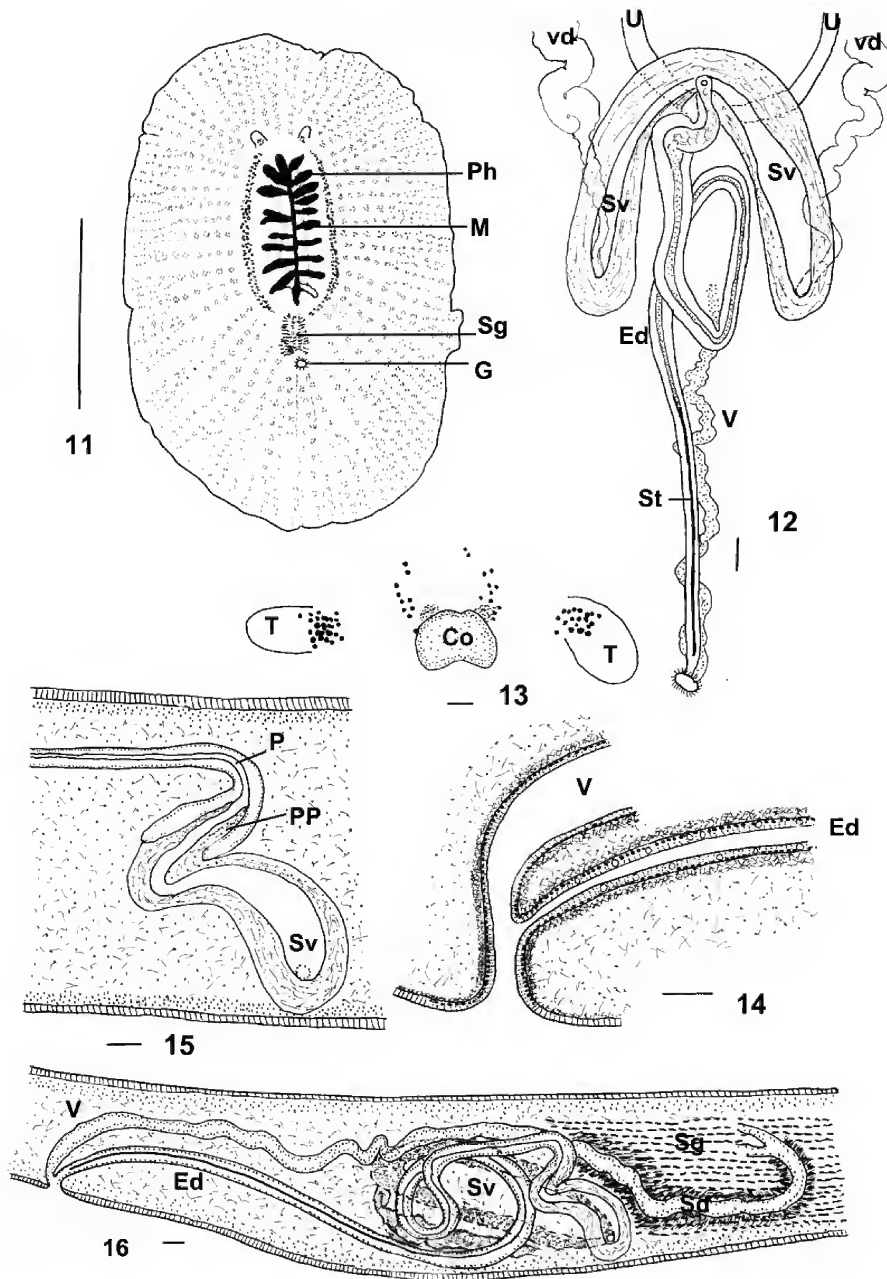
pharynx; elongated, convoluted ejaculatory duct, lined with glandular cells; penis armed with stylet; muscular, U-shaped seminal vesicle present; vagina elongate, directed anteriorly, dorsal to male genitalia; Lang's vesicle absent.

Type and only species: *Zygantrella queenslandensis* sp. nov.

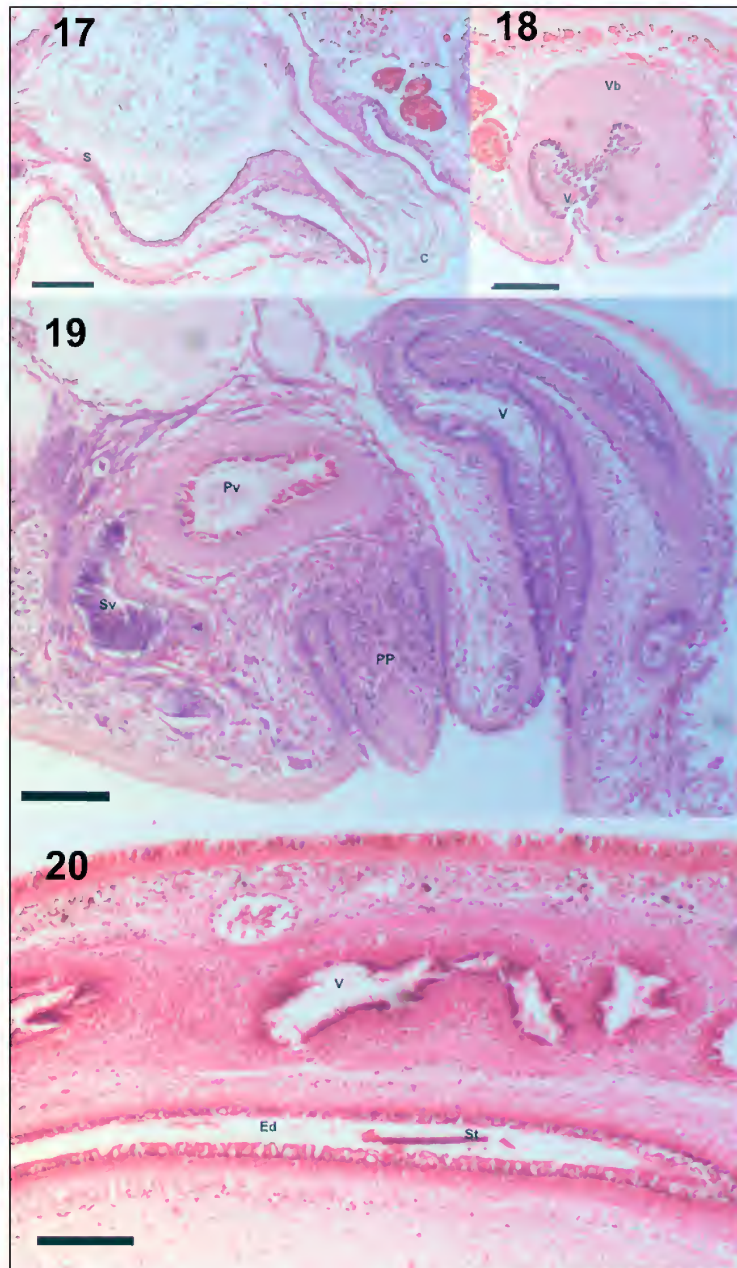
***Zygantrella queenslandensis* sp. nov.**
(Figs 11–16, 20)

Material examined. Holotype, inter-tidal, under rocks, Bowen, Queensland (20° 04'S 148° 22'E), coll. 15.vi.1997 (QM G235814); paratype, 1 specimen, same collection data (QM G235815); voucher specimens: 2 specimens, Wellington Point, Moreton Bay, Queensland (27° 25'S 153° 20'E), coll. 1.ix.1977, whole mounts (QM G235816, G238519) and 28 serial sections (QM G235820); 1 specimen, Rowe's Bay, Queensland (19° 16'S 146° 49'E), coll. 15.vii.2002, whole mount (QM G235817) and 17 serial sections (QM G235822); 1 specimen, same data, whole mount (QM G235821); 1 specimen, same locality, coll. 1.vii.1994 (QM G235818).

Description. Oval polyclads, 16–26 (20.6, n=7) long, maximum width 13–19 (15.4, n=7) (Fig. 11); pale, cream in colour with distinctly brown pharynx; lacking marginal eyes; with prominent elongate cerebral tentacles on either side of cerebral organ; cerebral organ bilobed, 0.35–0.50 (0.42, n=5) long, 0.45–0.60 (0.51, n=5) wide, 3.1–5.3 (3.9, n=5) from anterior extremity; cerebral eyes 12–15 in number in each of 2 elongate clusters lateral and anterior to cerebral organ; tentacular eyes at base of each tentacle, tightly clustered; c. 30 eyes in each cluster (Fig. 13). Pharynx plicate in anterior two thirds of body, immediately posterior to cerebral organ, with c. 12 ruffles, 4.2–6.0 (5.0) long; mouth just posterior to centre of pharynx 60–68 (63, n=3) % from anterior end of pharynx; intestinal branches mainly divaricate, non-anastomosing, few anastomoses adjacent to pharynx. Common gonopore, 3.6–5.5 (4.2, n=5) posterior to pharynx, 2.1–5.9 (3.8, n=5) from posterior extremity (Figs 12, 14). Ejaculatory duct elongate, convoluted, runs anteriorly from genital pore, lined with elongate cells with eosinophilic cytoplasm and basal nuclei and scattered vacuolated cells (Figs 14, 20); epithelium becomes columnar proximally and finally low columnar; distinct prostate



FIGS. 11-16. *Zygantrella queenslandensis* gen et sp. nov. 11, entire polyclad; 12, ventral view of terminal genitalia; 13, cerebral organ, tentacles and eyes; 14, longitudinal section through common genital gonopore; 15, longitudinal section through penis papilla and seminal vesicle; 16, longitudinal section through terminal genitalia; seminal vesicle and vas deferens shown on right side only. Scale bars: Fig. 11, 8 mm; Figs. 12-16, 0.1 mm. Legend: Co, cerebral organ; Ed, ejaculatory duct; G, gonopore; M, mouth; P, penis; Ph, pharynx; PP, penis papilla; Sd, shell duct; Sg, shell glands; St, stylet; Sv, seminal vesicle; T, tentacle; U, uterus; V, vagina; vd, vas deferens.



FIGS. 17-20. Transverse histological sections through the terminal genitalia. 17, *Amyris bulbosa* sp. nov., section through male gonopore showing everted cirrus and enlarged muscular sac surrounding terminal male genitalia; 18, *Amyris bulbosa* sp. nov., section through female gonopore showing distal vagina and muscular wall of globular vagina bulbosa; 19, *Emprostopharynx heroniensis* sp. nov., section through male and female gonopores showing seminal vesicle, prostatic organ, penis papilla and vagina; 20, *Zygantrella queenslandensis* gen et sp. nov, section through distal ejaculatory duct and vagina, showing epithelium. Scale bars: 1 mm. Legend: C, cirrus; Ed, ejaculatory duct; PP, penis papilla; Pv, prostatic vesicle; S, muscular sac surrounding terminal male genitalia; St, stylet; Sv, seminal vesicle; V, vagina; Vb, vagina bulbosa.

absent; penis elongate armed with prominent stylet c. 1.0 long (Fig. 12); penis papilla diminutive, within slight enlargement of proximal ejaculatory duct (Fig. 15); leads into large, muscular seminal vesicle, U-shaped in dorso-ventral view (Fig. 12); vasa deferentia arise from distal poles of each branch of seminal vesicle, coil anteriorly and laterally. Vagina elongate, sinuous, runs anteriorly from common genital pore, dorsal to ejaculatory duct (Figs 16, 20), lined with columnar, glandular epithelium, but lacking vacuolated cells; shell glands commence at level of seminal vesicle; vagina runs ventrally, then turns dorsally to run posteriorly; divides into two uterine ducts which initially run anteriorly, then turn laterally and again run anteriorly; entire parenchyma from level of seminal vesicle to recurrent region of vagina filled with eosinophilic shell glands, seen as mass obscuring male genitalia in whole mounts, 2.1–2.4 (2.3, n=2) long, 1.3–1.7 (1.5, n=2) wide in gravid specimens.

Remarks. The current species is difficult to place in the taxonomic system of Prudhoe (1985), with the dichotomous keys leading to a placement within *Phylloplana* Laidlaw, 1903, although it clearly does not comply with the generic description. Based on features of the genital system described in Prudhoe (1985), including the anterior direction of the vagina, dorsal to the male genitalia, the species described here has similarities with *Zygantriplana* Laidlaw, 1906, although again, there are several inconsistencies with the generic diagnosis provided by Prudhoe (1985).

In the taxonomic system of Faubel (1983), the species clearly belongs to the family Ilyplanidae Faubel, 1983, based primarily on the lack of a distinctive prostatic organ (superfamily Emprosthommatitidea Bock, 1913) and lacking prostatoids but with a penis stylet (Faubel 1983, p. 31). Faubel (1983) indicated (p. 36) that the family had been created for species in which the epithelial lining of the ejaculatory duct is of a glandular nature. This is the situation with the current species as no other identifiable prostatic tissue is identifiable; the glandular nature of the epithelium of the distal ejaculatory duct is shown in Fig. 14. Within the

family Ilyplanidae, the presence of a common genital atrium places the species close to *Zygantriplana*, a result similar to that using the descriptions of Prudhoe (1985). Prudhoe (1985) recognised six species within the genus: *Z. angusta* (Verrill, 1893), *Z. clepeastra* Kato, 1944, *Z. henriettae* Corrêa, 1949, *Z. plesia* Corrêa, 1949, *Z. stylifera* Hyman, 1953, *Z. verrilli* Laidlaw, 1906 and *Z. yrsa* du Bois-Reymond & Marcus, 1968.

Faubel (1983) by contrast divided these species into several, frequently monotypic genera, leaving *Z. verrilli* as the sole species of *Zygantriplana*, but transferring *Z. yrsa* to *Ilyella* Faubel, 1983, *Z. henriettae* and *Z. plesia* to *Zygantrioidea* Faubel, 1983, and *Z. clepeastra* to *Zygantrum* Faubel, 1983. *Zygantriplana angusta* and *Z. stylifera* were transferred to the family Stylochoplanidae Faubel, 1983 as *Alloioiplana stylifera* (Hyman, 1953) and *Compoplana angusta* (Verrill, 1893) respectively.

Following the system of Faubel (1983), the current species, in possessing a common genital atrium, is aligned with *Zygantrum*, *Zygantrioidea* and *Zygantriplana*, but does not comply fully with their generic descriptions.

The armed penis distinguishes this species from *Zygantrioidea* and *Zygantriplana*, thereby aligning it with *Zygantrum*, but it differs from this genus in that tentacles are present (absent in *Zygantrum*), eyes are distributed in discrete tentacular and cerebral groups (strewn over anterior third of body in *Zygantrum*) and Lang's vesicle is absent (present in *Zygantrum*).

Since this species cannot be accommodated within any of the currently recognised genera of the Ilyplanidae, a new genus, *Zygantrilla*, is proposed to accommodate it. Only a single species is currently attributable to this genus. The shape of the seminal vesicle also distinguishes this species from confamilial genera.

DISCUSSION

The finding of three new species of acotylean polyclads in Queensland is hardly surprising given the lack of study of the littoral platyhelminth fauna, particularly in the north of the state. That one of them requires a novel

genus to accommodate it is again not surprising, given the systematic re-arrangement of the acotyleans by Faubel (1983) which introduced large numbers of novel genera.

As indicated above, the different taxonomic systems for the acotylean polyclads adopted by Faubel (1983) and Prudhoe (1985) were taken into consideration when assessing each of the three new species described herein. It proved to be simpler to place each species within the system of Faubel (1983) even though this required the erection of a new genus.

The genus *Zyganetroplana*, as used by Prudhoe (1985) was split by Faubel (1983) into a number of frequently monotypic genera. Following the arrangement of Faubel (1983), the new species described here requires the erection of yet another monotypic genus, *Zygantralla*, based on several characters. The validity of these genera can only be tested by additional collections and descriptions.

The present descriptions of new species of acotylean polyclads, mainly from northern Queensland, continues to provide evidence of our lack of knowledge of this littoral platyhelminth fauna.

ACKNOWLEDGEMENTS

Thanks are due to Dr T.H. Cribb for organising the collection of polyclads at Wellington Point.

LITERATURE CITED

- Beveridge, I. 2000. Species of *Discocelis* (Platyhelminthes: Polycladida) from Queensland, with the description of a new species. *Memoirs of the Queensland Museum* **45**: 205–213.
- Beveridge, I. & Cribb, T.H. 2000. *Notoplana dubia* (Schmarda) (Platyhelminthes) from Queensland. *Memoirs of the Queensland Museum* **45**: 215–220.
- Bock, S. 1913. Studien über Polycladen. *Zoologische Bidrag fran Uppsala* **2**: 29–344.
- Faubel, A. 1983. The Polycladida, Turbellaria. Proposal and establishment of a new system. Part I. The Acotylea. *Mitteilungen aus dem Hamburgischen Zoologischen Museum und Institut* **80**: 17–121.
- Hyman, L.H. 1953. The polyclad flatworms of the Pacific coast of North America. *Bulletin of the American Museum of Natural History* **100**: 265–392.
- Jennings, K.A. & Newman, L.J. 1996a. Four new stylochid flatworms (Platyhelminthes: Polycladida) associated with commercial oysters from Moreton Bay, southeast Queensland, Australia. *The Raffles Bulletin of Zoology*, **44**: 493–508.
- Jennings, K.A. & Newman, L.J. 1996b. Two new stylochid flatworms (Platyhelminthes: Polycladida) from the southern Great Barrier Reef, Australia. *The Raffles Bulletin of Zoology* **44**: 135–142.
- Marcus, E. du Bois-Reymond & Marcus, E. (1968). Polycladida from Curaçao and faunistically related regions. *Studies on the fauna of Curaçao and other Caribbean Islands* **26**: 1–106.
- Newman, L.J. & Cannon, L.R.G. 1994a. Biodiversity of tropical polyclad flatworms from the Great Barrier Reef. *Memoirs of the Queensland Museum* **36**: 159–163.
- Newman, L.J. & Cannon, L.R.G. 1994b. *Pseudoceros* and *Pseudobiceros* (Platyhelminthes, Polycladida, Pseudocerotidae) from eastern Australia and Papua New Guinea. *Memoirs of the Queensland Museum* **37**: 205–266.
- Newman, L.J. & Cannon, L.R.G. 1995. The importance of the fixation of colour, pattern and form in tropical *Pseudocerotidae* (Platyhelminthes, Polycladida). *Hydrobiologia* **305**: 141–143. <https://doi.org/10.1007/BF00036376>.
- Newman, L.J. & Cannon, L.R.G. 1997a. Nine new species of *Pseudobiceros* (Platyhelminthes: Polycladida) from the Indo-Pacific. *The Raffles Bulletin of Zoology* **45**: 341–368.
- Newman, L.J. & Cannon, L.R.G. 1997b. A new semi-terrestrial acotylean flatworm, *Myoramyxa pardalota* gen. et sp. nov. (Plehnidae Polycladida) from southeast Queensland, Australia. *Memoirs of the Queensland Museum* **42**: 311–314.
- Newman, L.J. & Cannon, L.R.G. 2002. The genus *Cycloporus* (Platyhelminthes: Polycladida) from Australasian waters. *The Raffles Bulletin of Zoology* **50**: 287–299.
- Poche, F. 1926. Das System der Platoreria. *Archiv für Naturgeschichte* **A**: 1–485.
- Prudhoe, S. 1985. A monograph on polyclad turbellaria. (British Museum (Natural History) and Oxford University Press: Oxford). 259pp.
- Quatrefages, M.A. de 1845. Etudes sur les types inférieurs de l'embranchement des annélées. Mémoires sur quelques planariées marines appartenant aux genres *Tricelis* (Ehr.), *Polycelis* (Her.), *Prothiostomum* (Nob.), *Proceros* (Nob.), *Eolidiceros* (Nob.) et *Stylochus* (Her.). *Annales des Sciences Naturelles*, **30** série, **4**: 129–184.
- Sopott-Ehlers, B. & Schmidt, P. (1975). Interstielle Fauna von Galapagos. VI. Polycladida (Turbellaria). *Microfauna Meeresbodens* **54**: 193–222.

Helix namoiensis Cox, 1868: synonym of the North American zonitid *Mesomphix* (*Omphalina*) *cupreus* (Rafinesque, 1831)

Cox (1868) described *Helix namoiensis* with the accompanying type locality of Namoi River, New South Wales. Originally described in the Section *Patula*, this taxon was later referred to the family Rhytididae by Iredale (1933) and given separate generic recognition in the monotypic genus *Namoitena* Iredale, 1933. This was on account of the lack of sculpture on the upper surface of the teleoconch in contrast to the radially ribbed teleoconch of most other Australian rhytidids. Smith (1992) relegated *Namoitena* to a subgenus of *Strangesta* Iredale, 1933, included a range of other species, and placed *H. namoiensis* in the synonymy of the Sydney Basin *Strangesta strangei* (Pfeiffer, 1849). Both taxonomic decisions were made without supplied reasons. Following examination by the author of all rhytidid material in the collections of the Queensland and Australian Museums, in preparation for a field guide on eastern Australian land snails (Stanisic *et al.* 2010), the conclusion was that the type specimen, and only known specimen, did not represent an Australian species and so excluded this species from the Australian land snail fauna. This decision was also complemented by the author's personal knowledge of the land snails of the Namoi River drainage based on extensive field work in the area. Subsequent examination of overseas material in the Australian Museum showed that *Helix namoiensis* most closely resembled species of the Northern Hemisphere family Zonitidae, in particular the North American genus *Mesomphix*.

The specimen of *H. namoiensis* was presented to Cox by a friend, Mr Walker Scott, with no details of its origins (Cox 1868). One can only surmise that the spurious locality also came with the specimen.

The type specimen of *Helix namoiensis* (AMSC.87296) is sub-adult (diameter 21.5 mm) but is distinguished by its olive-brown colour, almost flat spire, worn apex, rounded whorls, open umbilicus and simple lip that is darkened on the outside, opalescent within. This combination of characters, in particular the worn apical whorls, externally blackened lip and open umbilicus correspond to that of *Mesomphix cupreus* (Rafinesque, 1831) from the eastern United States (Pilsbry 1946; Burch 1962). Illustrations of the two species are presented in Figure 1.

Hence the following new synonymies, in addition to those given in Pilsbry (1946), are proposed:

Mesomphix Rafinesque, 1819

Namoitena Iredale, 1933: 49; Iredale, 1938: 121; Smith 1992: 302 (as a subgenus of *Strangesta* Iredale, 1933).

Mesomphix cupreus (Rafinesque, 1831)

Helix namoiensis Cox, 1868: 29; Smith, 1992: 303 [as a synonym of *Strangesta strangei* (Pfeiffer, 1849)].

Namoitena namoiensis (Cox). Iredale, 1933: 49; Iredale, 1938: 121; Iredale, 1943: 69.

Literature Cited

- Burch, J.B. 1962. *How to know the eastern land snails*. (Wm.C. Brown Company Publishers: Dubuque). 214pp.
Cox, J.C. 1968. *A Monograph of Australian Land Shells*. (William Maddock: Sydney). 111 pp.

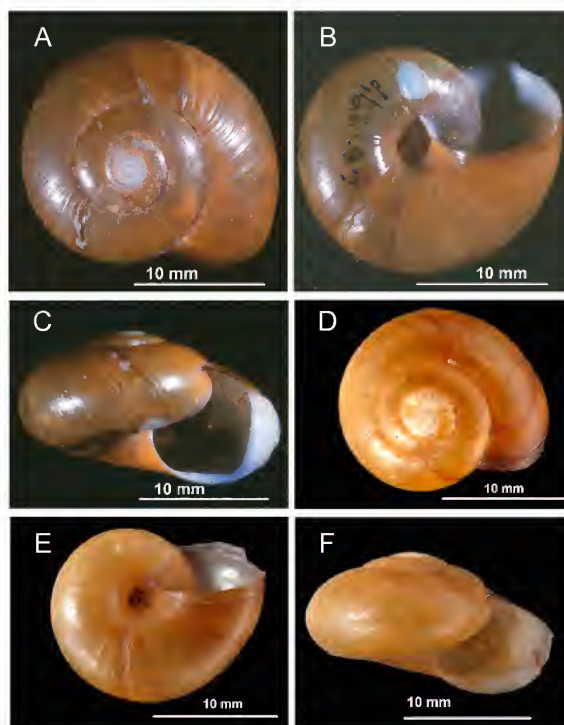


FIG. 1. A-C, *Helix namoiensis* Cox, 1868. Namoi River, New South Wales, holotype, AMSC.87296; D-F, *Mesomphix cupreus* (Rafinesque, 1831). Indiana, United States of America.

- Iredale, T. 1933. Systematic notes on Australian land shells. *Records of the Australian Museum* 19: 37-59. <https://doi.org/10.3853/j.0067-1975.19.1933.690>.
Iredale, T. 1938. A basic list of the land Mollusca of Australia. Part 3. *Australian Zoologist* 9: 83-124.
Iredale, T. 1943. Guide to the land shells of New South Wales. Part 5. *The Australian Naturalist* 9: 61-69.
Pfeiffer, L. 1849. *Monographia heliceorum viventium*. F.A. Brockhaus, Leipzig.
Pilsbry, H.A. 1946. Land Mollusca of North America (north of Mexico). *The Academy of Natural Sciences of Philadelphia, Monographs no. 3, Volume II, Part 1*: 1-520.
Rafinesque, C.S. 1831. *Enumeration and account of some remarkable natural objects of the cabinet of Prof. Rafinesque, in Philadelphia; being animals, shells, plants, fossils, collected by him in North America between 1816 and 1831*. Philadelphia, 1931.
Smith, B.J. 1992. Non-marine Mollusca. In: Houston, W.W.K. (ed.), *Zoological Catalogue of Australia*. Volume 8. (Australian Government Publishing Service: Canberra). 405pp.
Stanisic, J., Shea, M., Potter, D. & Griffiths, O. 2010. *Australian land snails. Volume 1. A field guide to eastern Australian species*. (Bioculture Press: Mauritius). 596pp.

Stanisic, J. 2018. Biodiversity Program, Queensland Museum, PO Box 3300, Qld 4101. Email: john.stanisic@qm.qld.gov.au. Accepted: 3 March 2018 Published online: 7 December 2018

<https://doi.org/10.1082/j.2204-1478.61.2018.2018-01>

LSID urn:lsid:zoobank.org:pub:D6F995BD-410B-4AD2-851B-2AFF3DDCCD51

Thirteen new charopid land snails from mid-eastern Queensland rainforests (Gastropoda: Eupulmonata: Charopidae)

Lorelle HOLCROFT

1. School of Environment, Griffith University; Australian Rivers Institute. Email: lorelle.holcroft@griffithuni.edu.au; lorelle.holcroft@bigpond.com; 2. Honorary Researcher, Biodiversity Program, Queensland Museum, PO Box 3300, South Brisbane, Qld 4101, Australia.

John STANISIC

Honorary Research Fellow, Biodiversity Program, Queensland Museum, PO Box 3300, South Brisbane, Qld 4101, Australia. Email: john.stanisic@qm.qld.gov.au

Citation: Holcroft, L. & Stanisic, J. 2018. Thirteen new charopid land snails from mid-eastern Queensland rainforests (Gastropoda: Eupulmonata: Charopidae). *Memoirs of the Queensland Museum-Nature* 61: 155-186. Brisbane. ISSN 2204-1478 (Online) ISSN 0070-8835 (Print). Accepted 3 September 2018. Published online: 21 December 2018.

<https://doi.org/10.17082/j.2204-1478.61.2018.2018-11>

LSID urn:lsid:zoobank.org:pub:F83B2D4E-76F8-4E4B-9F9A-81E55062D20D

ABSTRACT

Thirteen new species of charopid land snail are described from mid-eastern Queensland rainforests. These are assigned to four newly diagnosed genera: *Hirsutaropa sarina* gen. et sp. nov., *Burwellia staceythomsonae* gen. et sp. nov., *Albiropa microscopica* gen. et sp. nov., *Eungellaropa crediton* gen. et sp. nov. and six existing genera: *Lenwebbia marissae* sp. nov., *Omphaloropa subvaricosa* sp. nov., *Amfractaropa southpercyensis* sp. nov., *Comularopa wendyae* sp. nov., *Isolderopa gloucester* sp. nov., *Tristanoropa southmolle* sp. nov., *Tristanoropa summerae* sp. nov., *Tristanoropa jaxut* sp. nov. and *Tristanoropa hazelwood* sp. nov. An additional six species are recognised formally but not formally described due to poor quality material. New distribution data is presented for *Setomedeia janae* Stanisic, 1990, *Discocharopa aperta* (Möllendorff, 1888) and *Sinployea intensa* Iredale, 1941. The latter two represent new records for mid-eastern Queensland. A short discussion on the potential implications of the expanded MEQ charopid fauna for east coast biogeography is presented.

□ *Gastropoda, Eupulmonata, Charopidae, new genera, new species, mid-eastern Queensland.*

Until recently, knowledge of the charopid fauna of the extensive mid-eastern Queensland (MEQ) rainforests was limited to relatively few species. This was somewhat surprising considering that the family is the most speciose and numerically dominant group of land snails in other eastern Australian rainforests (Stanisic unpublished). Additions to the charopid fauna of MEQ has been incremental: Forbes (1851) the first to describe a single species; Hedley (1912) added a species; Iredale (1937) listed two species; Stanisic (1990) added one additional species; Smith (1992)'s catalogue of Australian

non-marine Mollusca listed three species; and Stanisic *et al.* (2010) featured 11 species of which eight were new. However, it was not until Holcroft (2018b) investigated the entire MEQ charopid holdings of the Queensland (QM) and Australian (AM) museums that the family's true diversity in these rainforests was uncovered. In doing so, the number of known species in MEQ was expanded from 11 to a possible 43, and most are new to science. The majority of species were from the mainland rainforests between Sarina and Proserpine, MEQ but several species were collected from

MEQ but several species were collected from off-lying islands which in fairly recent times (approximately 15 000 ybp) were connected to the mainland. Many of the putative new species (14) have been formally described in two systematic papers which also revised existing species (Holcroft 2018c, d).

In this paper we describe an additional thirteen species of MEQ Charopidae recorded by Holcroft (2018b) including some which were concealed among 'material examined' lists of more broadly defined species in that study. These new species are allocated to four newly diagnosed and six existing genera. We also present additional distribution data for three previously described species occurring in the region: *Setomedeia janae* Stanisic, 1990, *Discocharopa aperta* (Möllendorff, 1888) and *Sinployea intensa* (Iredale, 1941). The latter two are new records for MEQ.

A further six species are identified as putatively new from material listed in Holcroft (2018b) but are not formally described at this time because of poor quality material or material damaged during specimen preparation and handling. These damaged shells and fragments are documented and illustrated with brief accompanying remarks, not only to complete the species inventory, but more so to encourage and direct future investigations.

MATERIALS AND METHODS

The study is based on material revised in Holcroft (2018b). Individual specimens are identified by their registration number and respective institutional prefix (QMMO, Queensland Museum; AMSC, Australian Museum). Species not formally described are denoted by a family descriptor and alphanumeric codon that is used in both the QM's and AM's land snail databases to denote undescribed land snail species, e.g. Charopid MQ 43. Investigations of shell characters were carried out on specimens in the museums' dry collections (denoted as RC) by Holcroft and are presented in detail in Holcroft (2018b). Spirit specimens are denoted SC. Characters scored included shell height and diameter, whorl

count, rib count on the first whorl and umbilical width. Whorl counts were made to the nearest 1/8 whorl using the methodology of Solem (1983). Specimens were studied using a WILD M5 stereo microscope and shell photographs were taken using a NIKON 4200 Coolpix camera with microscope attachment. High resolution images of shells (260-600MB) were obtained using a Visionary Digital BK-Plus lab system camera set-up located in the Queensland Museum's Digital Imaging Unit. Shell sculpture was investigated and photographed using a TM-1000 Tabletop Scanning Electron Microscope at the Queensland Museum.

Shells were cleaned in an ultrasonic cleaner and not by chemical means in order to prevent the removal of the periostracum which shows many of the shell's sculptural elements. Shells used in the study were mostly recovered from leaf litter and occasionally were extremely fragile. In some cases the cleaning process and subsequent handling led to shell damage, some severe with only an illustration as evidence of the shell's morphology and its existence in MEQ.

Abbreviations used: General: SEM, scanning electron microscopy; SC, spirit collection; RC, dry collection.

Institutions: AM, Australian Museum, Sydney; QM, Queensland Museum, Brisbane.

Habitat Data: alt, altitude; Ck, Creek; CMC, Central Mackay Coast; cnvf, complex notophyll vine forest; Hts, Heights; I., Island; Mts, Mountains; nvf, notophyll vine forest; R, River; Ra, Range; sevt, semi-evergreen vine thicket; MEQ, Mid-eastern Queensland; NP, National Park; NSW, New South Wales; NENSW, North-eastern New South Wales; NEQ, North-eastern Queensland; SEQ, South-eastern Queensland; SF, State Forest; WT, Wet Tropics.

Generic differentiation and species delimitation

Holcroft (2018a) established a framework for using protoconch sculpture as a means of recognising putative genera in the absence of soft

parts for the study of reproductive structures and DNA analyses. Through the examination of the protoconch sculptures of 186 eastern Australian charopids (described and undescribed) by scanning electron microscopy her study concluded that this embryonic shell feature could provide a more reliable generic signature for members of the family than earlier *ad hoc* attempts had done (e.g., Iredale 1933, 1937, 1941a, b). This conclusion largely reflected the results of the most recent and only molecular-based study of eastern Australian charopids which showed a strong connection between protoconch sculptural pattern and DNA-based generic-level clades (Shea *et al.* 2012).

Thus new genera are diagnosed herein primarily on protoconch sculpture that is considered to be distinctive and differs from the sculptural patterns documented in previous studies (Stanisic 1990, Hyman & Stanisic 2005, Shea *et al.* 2012, Stanisic 2016, Holcroft 2018c, d). General shell features such as teleoconch sculpture and coiling pattern may also be important secondary considerations in generic determinations. New species are diagnosed on the basis of protoconch sculpture combined primarily with coiling pattern, shell shape and teleoconch sculpture.

SYSTEMATICS

Lenwebbia Stanisic, 1990

Lenwebbia Stanisic, 1990: 52; Smith, 1992: 192; Stanisic *et al.*, 2010: 256.

Type species. *Lenwebbia protoscribiculata* Stanisic, 1990 by original designation.

Diagnosis. Shell tiny, depressedly turbinata with a moderately raised, domed spire; whorls sub-angulate to rounded, sutures impressed; protoconch sculpture malleate, teleoconch with or without spiral grooves and fine thread-like radial ribs; umbilicus tiny, U-shaped. Colour yellowy-brown with darker grey spire.

Remarks. *Lenwebbia* Stanisic, 1990 differs from other east coast charopid genera primarily by a combination of malleate protoconch sculpture and reduced teleoconch sculpture. A malleate protoconch is highly unusual in

eastern Australian charopids and thus far seen elsewhere only in *Letomola* Iredale, 1941 from limestone outcrops in the Macleay Valley, NENSW (Hyman & Stanisic 2005).

Lenwebbia marissae sp. nov.

(Figs. 1A, B; 2A, B)

Etymology. Named for Marissa McNamara, Biodiversity Collection Manager, Queensland Museum.

Preferred Common name. Marissa's Pinwheel Snail.

Material examined. All MEQ. Holotype. QMMO77441, RC, Mt Dryander, 20° 15' S, 148° 33' E, 700 m, coll. QM party, 21.xi.1992. Height of shell 2.79 mm, diameter 4.43 mm, umbilical width 0.25 mm, H/D 0.63, D/U 18.00, number of whorls 4.500.

Paratype. QMMO85335, 1 subadult RC, Brandy Creek NP, rainforest, 20° 21' S, 148° 43' E, Litter, under logs, coll. J. Stanisic, L. Holcroft, 14.xi.2016.

Other material. AMSC154893, 1 subadult RC, Mt Dryander, 20° 15' S, 148° 32' E, 120m, coll. J. Burch, W. Ponder, P. Colman, 3.v.1975.

Diagnosis. Shell tiny, depressedly turbinata with a moderately raised domed spire; protoconch sculpture malleate, teleoconch sculpture of complex curved, irregularly spaced radial thickenings each comprised of several thin radial threads and spiral grooves; umbilicus tiny U-shaped.

Description. Shell tiny, yellow-brown, depressedly turbinata with a moderately raised domed spire; whorls 4.5 rounded, sutures impressed; diameter of shell 4.43 mm, height 2.79 mm, H/D 0.63. Protoconch sculpture malleate with scattered dimples, no spiral cords or radial ribs, diameter 660 µm; teleoconch sculpture of spiral grooves (Fig. 2A) and complex curved, irregularly spaced radial thickenings each comprised of several thin radial threads (Fig. 2B); umbilicus tiny, U-shaped, diameter 0.25 mm, D/U 18.0. Based on 1 measured adult specimen (QMMO77441).

Distribution and habitat. Brandy Creek and Mt Dryander, MEQ; in rainforest found under logs in litter.

Remarks. *Lenwebbia marissae* sp. nov. is similar to both *L. protoscribiculata* Stanisic, 1990 from the Kalpowar SF, SEQ and *L. paluma* Stanisic,

1993 from the Paluma Range, NEQ in general shell shape and size. However, *L. marissae* lacks the prominent spiral grooves evident on the teleoconch of *L. protoscrobiculata* and has reduced teleoconch sculpture more like that of *L. paluma* (see Stanisic 1993). Habitat preference for the drier araucarian rainforests of the Whitsunday bioprovince is similar to that of its congeners. Both *L. protoscrobiculata* and *L. paluma* live under bark of standing and fallen trees whereas *L. marissae* has only been found as dead shells in leaf litter. Hence lifestyle remains unknown. With the discovery of *L. marissae* in MEQ, *Lentwebbia* now spans a distribution range from SEQ, through MEQ to NEQ similar to that seen in *Setomedea* Iredale, 1941 (Stanisic 1990).

***Hirsutaropa* gen. nov.**

Type species. *Hirsutaropa sarina* sp. nov.

Etymology. From the Latin *hirsutus* = hairy, referring to the periostracal hair-like setae; and a contraction of *Charopa*.

Diagnosis. Shell tiny, flammulated, turbinata with an elevated spire and evenly coiled whorls; protoconch sculpture radial consisting of closely spaced, thin, slightly curved radial ribs, teleoconch sculpture of curved, widely spaced radial ribs and prominent thick spiral cords with a microsculpture comprised of crowded microradial threads; several spiral rows of widely spaced, stout, elongate setae located on the radial ribs; umbilicus narrowly open, U-shaped.

Remarks. *Hirsutaropa* gen. nov. differs from the hirsute *Setomedea* Iredale, 1941 by the combination of radial rather than spiral protoconch, depressedly turbinata rather than discoidal shell and sparse stout setae in contrast to the fine, crowded setae of the latter. The hirsute *Setoturbinata* Stanisic, 2010 from the Wet Tropics, NEQ is smaller, but differs by the combination of depressed conical spire, spiral protoconch, teleoconch with widely spaced, raised thin spiral cords and more scattered setae.

***Hirsutaropa sarina* sp. nov.**
(Figs 1C, D; 2C, D)

Etymology. For the township of Sarina.

Preferred Common name. Sarina Hairy Pinwheel Snail.

Material examined. Holotype. QMMO77399, RC, Sarina, SW at Upper East Funnel Ck, MEQ, 21° 34' S, 149° 12' E, 200m, coll. QM party, 16.xi.1992. Height of shell 2.3 mm, diameter 3.69 mm, umbilical width 0.82 mm, D/U 4.50, H/D 0.62, whorls 4.0.

Diagnosis. As for genus.

Description. Shell tiny, brown with darker radial streaks (flammulations), turbinata with an elevated spire and 4 evenly coiled whorls, sutures moderately impressed; diameter of shell 3.69 mm, height 2.3 mm, H/D 0.62. Protoconch damaged and only last quarter visible, radial with sculpture of closely spaced, thin, slightly curved radial ribs (Fig. 2C); teleoconch sculpture of curved, widely spaced radial ribs and prominent spiral cords with a microsculpture comprised of crowded microradial threads (Fig. 2D); several spiral rows of widely spaced, stout, elongate setae located along the major radial ribs; aperture ovately lunate; umbilicus narrow U-shaped, diameter 0.82 mm, D/U 4.50.

Distribution and habitat. Known only from the type locality at Upper East Funnel Creek, MEQ; in rainforest found in litter.

Remarks. *Hirsutaropa sarina* sp. nov. is known only from the holotype specimen but is readily distinguishable from other MEQ charopids by the combination of turbinata, flammulated shell with radial protoconch, narrow umbilicus and scattered, stout elongate setae on the teleoconch. In contrast the superficially similar *Setomedea janae* Stanisic, 1990 has a flammulated, discoidal shell with spiral protoconch, wide umbilicus and relatively crowded, short and fine periostracal setae. Although the protoconch of the *H. hirsuta* holotype is damaged the last quarter is intact and shows a sculpture of curved radial ribs without any spiral elements (Fig. 2C).

Setomedeia Iredale, 1941

Setomedeia Iredale, 1933: 53; 1937: 329-nomina nuda.

Setomedeia Iredale, 1941: 267-valid description (Stanisic, 1990: 57); Stanisic *et al.*, 2010: 242.

Type species. *Sutera seticostata* Hedley, 1924-by original designation.

Diagnosis. Shell tiny, creamy yellow with reddish zigzag flammulations, discoidal with a low to flat spire; whorls rounded, sutures impressed; protoconch superior spiral with weak to strong squiggly spiral cords and weaker radial ribs, teleoconch with regularly spaced, curved radial ribs and with or without short crowded setae, microsculpture of microradial threads and low microspiral cords; umbilicus narrow V-shaped to wide U-shaped.

Remarks. The original introduction (Iredale 1933) and subsequent citation (Iredale 1937) were considered invalid by Stanisic (1990). The following are new records for *Setomedeia* Iredale, 1941 in MEQ and additional to those given in Stanisic (1990).

***Setomedeia janae* Stanisic, 1990**
(Figs 1E, F; 2E, F)

Setomedeia janae Stanisic, 1990: 69; Smith, 1992: 205; Stanisic *et al.* 2010: 242.

Type locality. Mt Dryander, MEQ.

Common name. Jan's Pinwheel Snail.

Material examined. All MEQ. QMMO35546, Mt Dryander, lower slopes, via Gregory, NE Proserpine, 20° 17' S, 148° 35' 30" E, coll. J. Stanisic, D. Potter, 16.v.1990; QMMO35620, Mt Macartney slopes, Cathu Forest Dve, SW Proserpine, 20° 20' S, 148° 33' E, 18.v.1990; QMMO35632, Mt Macartney slopes, Cathu Forest Dve, SW Proserpine, 20° 20' S, 148° 33' E, 900 m, coll. J. Stanisic, D. Potter, 18.v.1990; QMMO36092, Mt Dalrymple, lower slopes, Eungella, 21° 04' S, 148° 35' E, coll. J. Stanisic, D. Potter, N. Potter, 21.v.1990; QMMO77233, Sarina, SW at Blue Mts, c.0.6k SE, 21° 36' S, 148° 58' E, 930 m, coll. G. Monteith, 23.iii.2000; QMMO77236, Sarina, SW at Blue Mts, c.0.6k SE, 21° 36' S, 148° 58' E, 930 m, coll. G. Monteith, 23.iii.2000; QMMO77322, Sarina, SW at Blue Mts, c.0.6 km SE, pitfall trap, 21° 36' S, 148° 58' E, 930 m, coll. G. Monteith, D. Cook, 30.v.2000; QMMO77326, Sarina, SW at Blue Mts, c.0.6k SE, 21° 36' S, 148° 58' E, 950 m, coll. G. Monteith, 31.v.2000; QMMO77328, Sarina, SW at Blue Mts, c.0.6k SE, 21° 36' S, 148° 58' E, 900 m, coll. QM party, 31.v.2000;

QMMO77432, Eungella NP, at Upper Cattle Ck, 21° 02' S, 148° 36' E, 900 m, coll. QM party, 17.xi.1992; QMMO77466, Proserpine, S at Mt Macartney, 20° 50' S, 148° 34' E, 900 m, coll. QM party, 19.xi.1992; QMMO85175, Eungella NP, Mt Henry, rainforest, 21.026° S, 148.627° E, 1200 m site 2, under logs, 1164 m, coll. J. Stanisic, 14.xi.2013.

Description. Shell small (mean diameter 3.64 mm), pale yellow with reddish flammulations, discoidal with a flat spire and rounded whorls. Protoconch spiral, sculptured with squiggly spiral cords over weak radial undulations, teleoconch with prominent radial ribs and with a dense covering of moderately long periostracal setae; umbilicus open U-shaped.

Remarks. *Setomedeia janae* Stanisic, 1990 is the sole representative of the genus in MEQ. *Setomedeia janae* is distinguished by the flammulated, discoidal shell with dense covering of periostracal setae and differs from *Hirsutiaropa sarina* sp. nov. which has a flammulated, turbinat shell with sparsely scattered setae. Additional species of *Setomedeia* occur in SEQ and NEQ (Stanisic 1990, Stanisic *et al.* 2010), some without setae.

***Burwellia* gen. nov.**

Type species. *Burwellia staceythomsonae* sp. nov.

Etymology. For Chris Burwell, Senior Entomologist, Queensland Museum.

Diagnosis. Shell minute, white, discoidal with a flat spire; protoconch superior radial consisting of closely spaced, bold and weakly curved radial ribs and numerous, crowded, thin spiral cords that rise over the radials forming elongate beads on the apex of the radial; teleoconch with crowded, bold radial ribs and numerous, crowded, weak microradial threads and prominent microspiral cords that form a bead at their intersection; umbilicus pinhole, narrowly open, U-shaped.

Remarks. *Burwellia* gen. nov. is readily distinguished from other MEQ charopid genera by its minute, white discoidal shell with superior radial protoconch sculpture

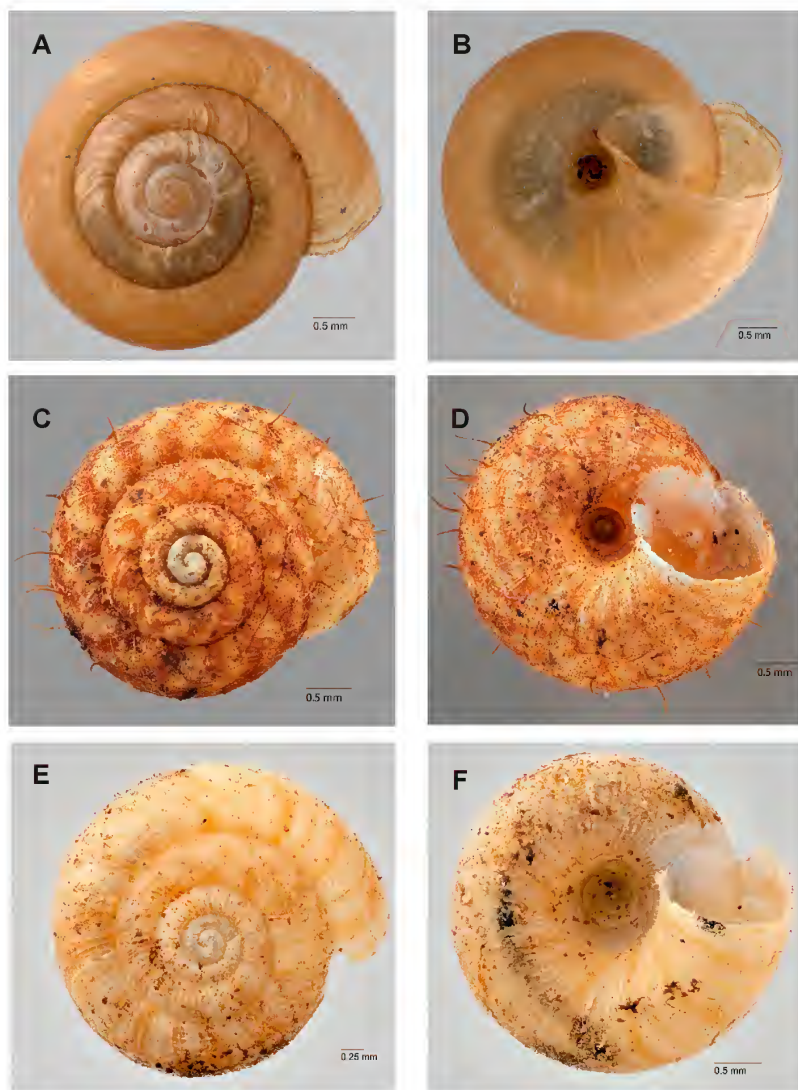


FIG. 1. A-B, *Lenwebbia marissae* sp. nov., QMMO77441, holotype, Mt Dryander, MEQ. A, apical view; B, umbilical view. C-D, *Hirsutiaropa sarina* gen. et sp. nov., QMMO77399, holotype, Funnel Creek, MEQ; C, apical view; D, umbilical view. E-F, *Setomedeia janae*, QMMO36092, Mt Dalrymple, MEQ; E, apical view; F, umbilical view. Images A-F: Geoff Thompson, QM. Scale lines as marked.

consisting of bold radial ribs and thin spiral cords, teleoconch with widely spaced, bold radial ribs and very narrow umbilicus. The general shell facies consisting of prominent bold ribbing on both protoconch and teleoconch is more like that seen in genera from limestone outcrops rather than rainforest (see Hyman & Stanisic 2005).

***Burwellia staceythomsonae* sp. nov.**
(Fig. 3A-D)

Etymology. Named for Stacey Thomson, presenter on the popular television program *Totally Wild* and former national parks ranger.

Preferred Common name. Ranger Stacey's Pinwheel Snail.

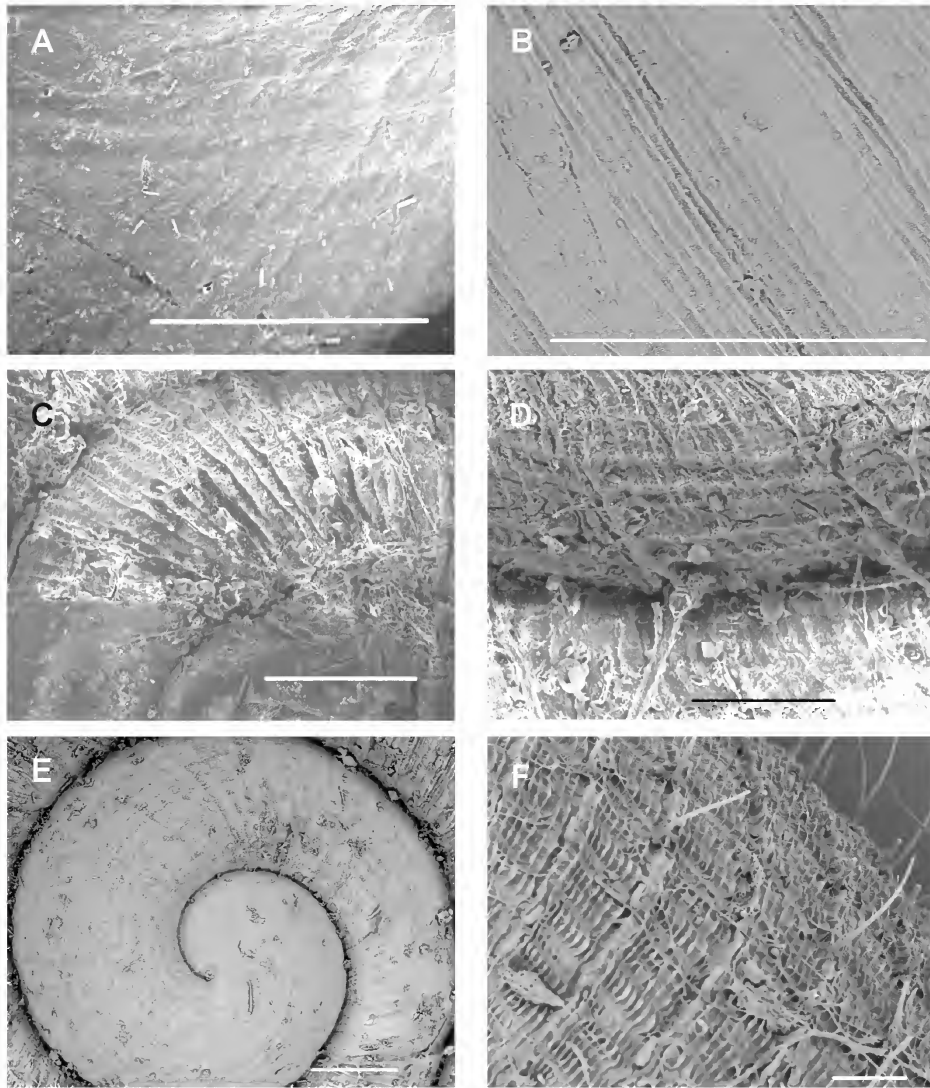


FIG. 2. A-B, *Lenwebbia marissae* sp. nov., QMMO77441, holotype, Mt Dryander, MEQ. Teleoconch sculpture showing vague spiral grooves (A) and complex radial ribs (B); C-D, *Hirsutiaropa sarina* gen. et sp. nov., QMMO77399, holotype, Funnel Creek, MEQ. C, protoconch showing radial ribs; D, teleoconch showing long setae attached to major radial ribs and thick spiral cords; E-F, *Setomedeia janae*, QMMO36092, Mt Dalrymple, MEQ. E, protoconch with spiral cords; F, teleoconch sculpture showing fine setae. Scale bars = 100 μ .

Material examined. Holotype. QMMO85089, RC, Eungella NP, Mt Dalrymple track, rainforest, MEQ, 21.026°S, 148.627°E, 1200 m site 3, litter, 1144 m, coll. A. Nakamura, E. Leach, 2-12.iv.2014. Height of shell 0.82 mm, diameter 1.48 mm, width of umbilicus 0.25 mm, D/U 6.00, H/D 0.56, whorls 4.0.

Diagnosis. As for genus.

Description. Shell minute, white, discoidal with a flat spire; whorls 4 evenly coiled, sutures moderately impressed; diameter of shell 1.48 mm, height 0.82 mm, H/D 0.56. Protoconch superior radial, diameter 250 μ m, sculptured with prominent, bold and widely spaced radial ribs which increase in frequency the closer to the protoconch-teleoconch boundary

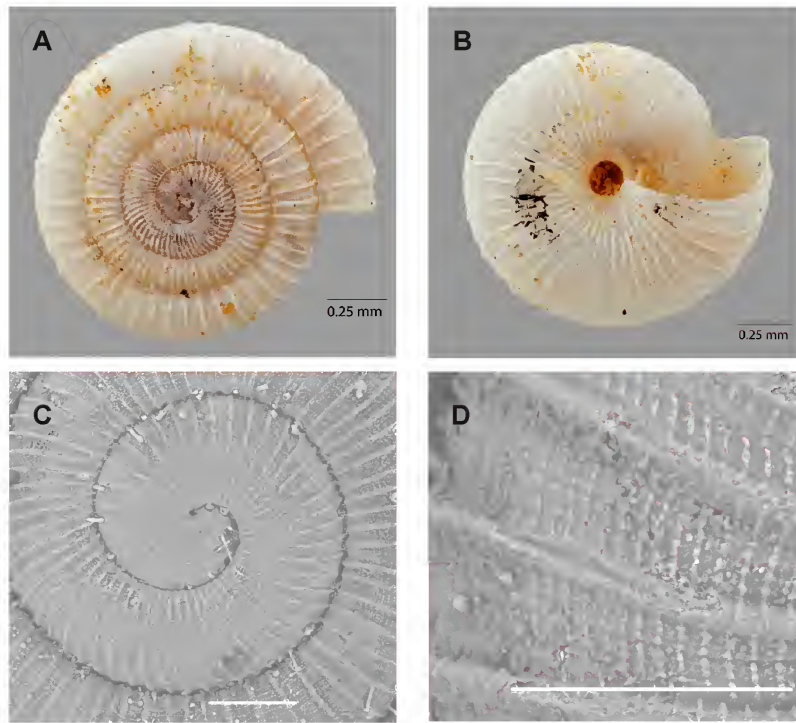


FIG. 3. *Burwellia staceythomsonae* gen. et sp. nov., QMMO85089, holotype, Mt Dalrymple, MEQ. **A**, apical view; **B**, umbilical view; **C**, bold radial ribs on protoconch; **D**, teleoconch sculpture showing bold radial ribs and beaded microsculpture. A-B: scale lines as marked; C-D: scale bars = 100µm. Images A-B: Geoff Thompson, QM.

and numerous thin, spiral cords rising over the radial ribs where they form an elongate bead; teleoconch with bold, rounded radial ribs, 47 on the first whorl; microsculpture of numerous, crowded weak microradial threads and prominent microspiral cords that cross the microradials and form a bead at their intersection; aperture ovately lunate; umbilicus pinhole, narrow U-shaped, diameter 0.25 mm, D/U 6.00. Based on 1 measured adult specimen (QMMO85089).

Distribution and habitat. Eungella NP, MEQ; in moist humid rainforest, found in litter.

Remarks. *Burwellia staceythomsonae* sp. nov. is unique among MEQ charopids in being the only one with a superior radial protoconch sculpture consisting of very broad, straight-sided, widely spaced radial ribs (Fig. 3C). The radially ribbed, white shell with tiny pinhole umbilicus and

large D/U ratio readily separate this species from the many MEQ charopid species of similar shell dimensions. No comparable charopid species has been encountered among the many MEQ charopid specimens thus far examined and the shell morphology is unusual for a high altitude rainforest specialist. *B. staceythomsonae* has all the attributes of a rainforest relict but at this time is known only from a single shell specimen from the higher reaches of Mt Dalrymple (alt. 1144 m). Additional collecting for live material in all the higher elevations of Eungella NP is needed to determine the full extent of its distribution and affinities.

Albiropa gen. nov.

Type species. *Albiropa microscopica* sp. nov.

Etymology. From the Latin *albus* = white, referring to the white shell; and a contraction of *Charopa*.

Diagnosis. Shell minute, white, discoidal with rounded whorls; protoconch sculpture radial comprising densely crowded, curved radial ribs and short, interrupted spiral wrinkles; teleoconch with very crowded, bladed radial ribs, microsculpture of prominent simple microradial threads overlaying numerous, low microspiral cords forming elongate beads at their intersection; umbilicus wide saucer-shaped.

Remarks. Differs from the very similar *Discocharopa* Iredale, 1913 by having more crowded radial ribs on the protoconch (compare Figs. 4C and 4G), spiral cords on the teleoconch and a smaller cup-shaped rather than wide saucer-shaped umbilicus.

***Albiropa microscopica* sp. nov.**
(Fig. 4A–D)

Etymology. Referring to the minute size of the species.

Preferred Common name. Microscopic Pinwheel Snail.

Material examined. All MEQ. Holotype, QMMO86563, RC, Diamond Cliffs, Homevale NP, 21°22'59" S, 148°34'21" E, coll. QM Party, 14.x.2005. Height of shell 0.66 mm, diameter 1.15 mm, width of umbilicus 0.41 mm, D/U 2.80, H/D 0.50, whorls 3.250.

Paratypes. QMMO85314, 4 partly broken adult and subadult shells RC, same data as holotype.

Other material. QMMO85313, 1 damaged adult RC, Calen - Mt Charlton Rd, c.17.5 km W Calen, 21°00' S, 148°42' E, coll. J. Stanisic, 6.vii.1982; QMMO85091, 1 damaged adult RC, Eungella NP, Finch Hatton Gorge, 21°03'39.6" S, 148°38'16.8" E, 766 m, coll. C. Burwell, C. Gely, 18.iii.2014.

Diagnosis. As for genus.

Description. Shell minute, white, discoidal with a flat spire; whorls 4 multicoiled; sutures moderately impressed; diameter of shell 1.07–1.31 mm (mean 1.20 mm), height 0.57–0.74 mm (mean 0.66 mm), H/D 0.50–0.62 (mean 0.55); protoconch flat, diameter 330 µm, sculpture radial with extremely crowded, curved radial ribs and spiral periostracal wrinkles; teleoconch with bladed crowded radial ribs, 69–100 (mean 88) on the first whorl; microsculpture of prominent, simple microradial threads overlaying numerous, low microspiral cords forming elongate beads at their intersection;

aperture ovately lunate; umbilicus wide saucer-shaped, diameter 0.41–0.49 mm (mean 0.44 mm), D/U 2.17–3.20 (mean 2.73). Based on 5 measured adult specimens (QMMO85313 [1], QMMO85314 [4]).

Distribution and habitat. Mt Charlton, Finch Hatton Gorge and Diamond Cliffs, MEQ; in rainforest living in litter.

Remarks. *Albiropa microscopica* sp. nov. is a tiny white species which is easily confused with *Discocharopa aperta* (Möllerndorff, 1888) which also has a minute white shell, radial protoconch sculpture and a similar number of radial ribs on the teleoconch. However a key distinguishing feature is in the teleoconch sculpture. *Albiropa microscopica* has a radially ribbed teleoconch with simple interstitial microradial riblets and low, broad microspiral cords which form elongate beads when they intersect with the microradial riblets (Fig. 4D). *Discocharopa aperta* has a similar radial teleoconch but the interstitial microradial riblets have serrate apices and there is no microspiral sculpture (Fig. 4H). Furthermore the protoconch of *A. microscopica* is smaller at 330 µm as compared to 410 µm in *D. aperta* and the radial ribbing is more crowded. This species appears to inhabit the slightly wetter rainforest environments of MEQ as opposed to *D. aperta* which prefers drier araucarian rainforest and dry vine thickets.

***Discocharopa* Iredale, 1913**

Discocharopa Iredale, 1913; Iredale 1937 (in part); Stanisic, 1992; Smith, 1992 (in part); Stanisic *et al.* 2010 (in part).

Type species. *Charopa* (*Discocharopa*) *exquisita* Iredale, 1913-by original designation.

Diagnosis. (amended from Stanisic 2010). Shell minute, white, discoidal with a flat spire; whorls rounded, suture weakly impressed; protoconch radial comprising slightly curved, crowded radial ribs and interrupted spiral wrinkles, teleoconch with curved and crowded radial ribs and microsculpture of thin serrated microradial threads; umbilicus wide cup to wide saucer-shaped.

Remarks. The lack of spiral sculpture on the teleoconch readily distinguishes *Discocharopa* from *Albiropa* gen. nov. Stanisic (1990) included several additional species in *Discocharopa* for convenience while acknowledging that the genus as defined therein was most likely polyphyletic. Following examination of these species by SEM it would appear that *Discocharopa* is most likely monotypic and that the additional species belong elsewhere. The following represent the first formally documented records of the genus in MEQ.

***Discocharopa aperta* (Möllerndorff, 1888)**
(Fig. 4E-H)

Patula aperta Möllerndorff, 1888 (Philippines).
Endodonta (*Charopa*) *planorbulina* Tate, 1896 (Central Australia).
Endodonta concinna Hedley, 1901 (Bundaberg, Qld).
Charopa (*Discocharopa*) *exquisita* Iredale, 1913 (Kermadec Island).
Discocharopa concinna (Hedley). Iredale, 1937: 325.
Discocharopa aperta (Möllerndorff). Solem, 1957 (New Hebrides); Stanisic, 1990: 143 (Eastern Australia); Stanisic *et al.*, 2010: 216 (Eastern Australia).

Type locality. Montalban, Luzon, Philippines.

Common name. Miniscale White Pinwheel Snail.

Material examined. All MEQ. QMMO13098, Endeavour Ck, c.17.5 km W Calen, 21°00' S, 148°42' E, 900 m, coll. J. Stanisic, D. Potter, N. Potter, 18.v.1990; QMMO50882, Eungella NP, Rocky Ck, 20°54' S, 148°36' E, coll. G. Annabell, 12.v.1988; QMMO73832, Long I, NE Side on Whitsunday Circuit, 20°19'44" S, 148°51'27" E, J. Stanisic, D. Potter, 15.vi.1987; QMMO77074, Mackay, WSW at Diamond Cliffs, Homevale NP, 21°22'59" S, 148°34'21" E, coll. J. Stanisic, D. Potter, N. Potter, 17.v.1990; AMSC152150, Brandy Creek SF, E of Proserpine, 20°21' S, 148°43' E, 120 m, cnvf, litter, coll. J. Burch, W. Ponder, 2.v.1975

Description. Shell minute (mean diameter 1.31 mm), white with evenly coiled, rounded whorls and impressed sutures. Protoconch radial sculptured with curved and crowded radial ribs and scattered short spiral wrinkles, teleoconch with prominent crowded curved radial ribs, microsculpture of serrated microradial threads, 3-5 between each major rib; umbilicus wide, saucer-shaped.

Remarks. *Discocharopa aperta* is an extremely widespread and well known species (as seen in the synonymy above), occurring in the drier

forests and vine thickets of tropical and sub-tropical Australia and many areas extralimital to the continent (see Solem 1983). The species' discovery in MEQ was not unexpected given the presence of drier rainforest in the region and this is the first opportunity to formally document its presence in the bioregion. *D. aperta* differs from *Albiropa microscopica* sp. nov. by the lack of spiral sculpture on the teleoconch and in having serrated rather than simple microradial threads (Fig. 4H). In general appearance the teleoconch sculpture of *D. aperta* is coarser than that of *A. microscopica*.

***Omphaloropa* Stanisic, 1990**

Omphaloropa Stanisic, 1990: 198; Smith 1992: 196; Stanisic *et al.* 2010: 252.

Type species. *Omphaloropa varicosa* Stanisic, 1990-by original designation.

Diagnosis. Shell tiny, subdiscoidal with an elevated, domed and rounded whorls. Protoconch spiral consisting of low, broad, widely spaced spiral cords, teleoconch sculpture of very widely spaced, bold radial ribs, microsculpture of low microradial threads that are continuous on the major ribs and low, crowded, prominent spiral cords that form beads at the intersection with the microradial threads; umbilicus wide, cup-shaped.

***Omphaloropa subvaricosa* sp. nov.**
(Fig. 5A-D)

Etymology. Alluding to its close similarity to the genotype.

Preferred Common name. Wide-ribbed Pinwheel Snail.

Material examined. All MEQ. Holotype. QMMO86564, RC, Hatfields Gap, Koumala-Bolingbroke Rd, vine forest, 21°33' S, 149°11' E, under logs, coll. J. Stanisic, L. Holcroft, 19.xi.2016. Height of shell 1.48 mm, diameter 2.87 mm, width of umbilicus 1.07 mm, D/U 2.54, H/D 0.58, whorls 4.625.

Paratypes. QMMO85346, 2 subadult RC, same data as holotype; QMMO85341, 1RC, Cherry Tree Ck, 1.2 km of Pinnacle Station Rd, 21°12' S, 148°42' E, under rocks and logs, vine forest, coll. J. Stanisic, L. Holcroft, 17.xi.2016.

Diagnosis. Shell tiny, subdiscoidal with an elevated domed spire; protoconch spiral comprising widely spaced, broad spiral cords,

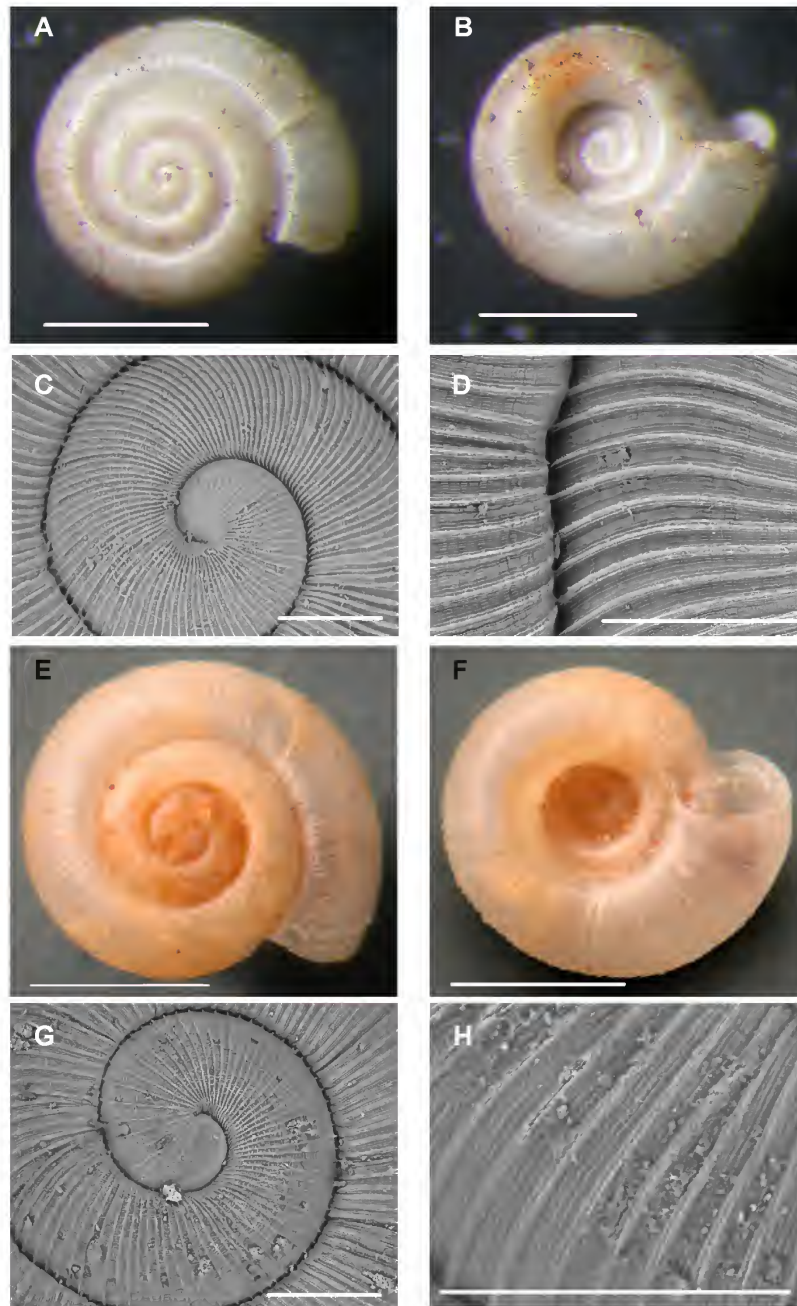


FIG. 4. A-D, *Albiropa microscopica* gen. et sp. nov., Diamond Cliffs, MEQ. A-B, QMMO85314, paratype. A, apical view. B, umbilical view. C-D, QMMO86563, holotype. C, protoconch showing crowded radial ribs and continuous spiral cords; D, teleoconch showing broad spiral cords and elongate beading. E-H, *Discocharopa aperta*, E-F, QMMO17312, Mt Etna, SEQ. E, apical view; F, umbilical view. G, AMSC152150, Brandy Creek, Conway NP, MEQ. Protoconch showing radial ribs and interrupted spiral wrinkles. H, QMMO50882, Rocky Creek, Eungella NP, MEQ. Teleoconch showing serrated microradial ribs. A-B, E-F: scale lines = 0.5 mm; C-D, G-H: scale bars = 100µm.

teleoconch with widely spaced, bladed radial ribs, mean 22 on the first whorl; microsculpture of raised microradial threads continuous on the major ribs and low, crowded, prominent spiral cords; umbilicus wide saucer-shaped.

Description. Shell tiny, golden-brown, sub-discoidal, with an elevated domed spire; whorls rounded 4.375–4.675, sutures strongly impressed; diameter of shell 2.54–2.70 mm (mean 2.70 mm), height 1.39–1.50 mm (mean 1.56 mm), H/D 0.51–0.58 (mean 0.55). Protoconch flat of 1.5 whorls, diameter 570 μ m, sculpture spiral with widely spaced, broad spiral cords, teleoconch with widely spaced, bladed radial ribs, 17–25 (mean 22) on the first whorl; microsculpture of raised microradial threads continuous on the major ribs and low, crowded, prominent spiral cords that form beads at the intersection with the microradial threads; aperture ovately lunate with margins approximating; umbilicus wide saucer-shaped, diameter 0.98–1.07 (mean 1.05 mm), D/U 2.54–2.69 (mean 2.59). Based on 4 measured adult specimens (QMMO85346 [3], QMMO85341 [1]).

Distribution and habitat. Thus far only known from Cherry Tree Creek (Crediton SF) and Hatfield's Gap, MEQ; in dry rainforest living under rocks and logs.

Remarks. *Omphaloropa subvaricosa* sp. nov. represents the first record of the genus in MEQ. A single species *O. varicosa* Stanisic, 1990 was previously recorded from SEQ (Stanisic 1990). *Omphaloropa subvaricosa* differs from its southern congener in having a larger, monochrome golden-brown shell characterised by larger diameter whorls, regularly spaced radial ribs on the teleoconch, a more elevated spire and smaller umbilicus. *O. varicosa* has a smaller, flammulated shell with more closely spaced radial ribs on the teleoconch that become very crowded and irregular on the last quarter of the body whorl. The apparent disjunct distribution of *O. subvaricosa* in the geographically distant rainforests of Cherry Tree Creek in the Crediton SF, Clarke Range and those of Hatfields Gap on the eastern escarpment of the Clarke Range may simply reflect an artefact of collecting with the gap

liable to be filled with additional fieldwork. Alternatively, the distribution may represent a species that has survived continental aridification but has been restricted in range as broadacre rainforests gave rise to smaller isolated patches of dry vine forest.

Sinployea Solem, 1983

Sinployea Solem, 1983: 81; Stanisic, 1990: 205; Smith, 1992: 205; Stanisic *et al.*, 2010: 248.

Type species. *Sinployea peasei* Solem, 1983-by original designation.

Diagnosis. Shell tiny, cinnamon brown, discoidal with a low to flat spire; whorls rounded, sutures deeply impressed; protoconch spiral comprising low, flattened widely spaced spiral cords, teleoconch sculpture of crowded, curved radial ribs, microsculpture of microradial threads and low spiral cords; umbilicus wide V-shaped.

Remarks. Stanisic (1990) introduced the chiefly Pacific Basin *Sinployea* Solem, 1983 to the Australian region for the first time for *Cralopa intensa* Iredale, 1941 from Byron Bay, NE NSW and extended the range of the species to near Gladstone, SEQ. Subsequently Stanisic (in Stanisic *et al.* 2010) also added *Endodonta* (*Charopa*) *intermedia* Odhner, 1917 from the Wet Tropics, NEQ to the genus. The following records of *S. intensa* represent the first records of the genus in MEQ.

Sinployea intensa (Iredale, 1941) (Figs 6A, B; 7A, B)

Cralopa intensa Iredale, 1941a: 269.

Sinployea intensa (Iredale). Stanisic, 1990: 206; Stanisic *et al.*, 2010: 248.

Type locality. Byron Bay, NENSW.

Common name. Southern Cinnamon Pinwheel Snail.

Material examined. All MEQ. QMMO11733, c. 19k N. of Proserpine, beside Gregory R., 20°17' S, 148°35' E, J. Stanisic, 6.vii.1982; QMMO13084, Bells Gap, Sarina Ra, c.15 km S Sarina, 21°31' S, 149°07' E, J. Stanisic, 7.vii.1982; QMMO13454, Eungella NP, Broken R, 21°10' S, 148°30' E, J. Stanisic, 5.vii.1982; QMMO13475, c. 36.7k N. of Mackay, on Mackay-Seaforth Rd., 21°00' S, 148°52' E, J. Stanisic, 3.vii.1982; QMMO35808, Endeavour Ck, Upper Reaches, Clarke Ra, W of Mackay, 21°15'30" S, 148°37'30" E, coll. J. Stanisic, D. Potter, N. Potter, 20.v.1990; QMMO59644, Eungella NP, Dalrymple

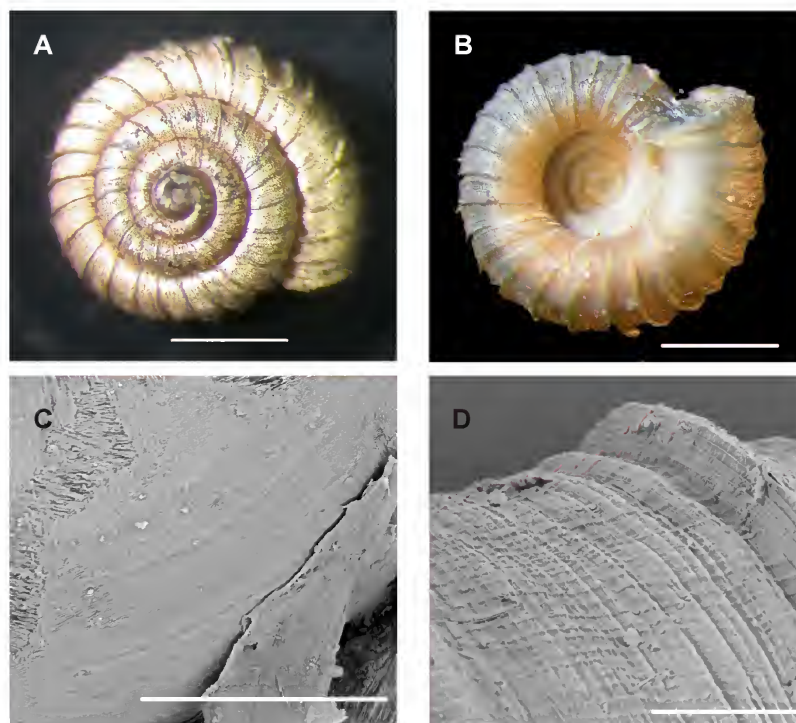


FIG. 5. *Omphaloropa subvaricosa* sp. nov., QMMO86564, holotype, Hatfields Gap, MEQ. A, apical view; B, umbilical view; C, protoconch showing low, widely spaced spiral cords; D, teleoconch showing microsculpture. A-B: scale lines = 1 mm; C-D: scale bars = 100 μ m.

Heights, 21°2' S, 148°36' E, 1000 m, coll. M.J. Bishop, xi.1976; QMMO35621, Mt Macartney, slopes, Cathu Forest Drive, SW Proserpine, 20°50' S, 148°33' E, 800 m, coll. J. Stanisic, D. Potter, N. Potter, 18.v.1990.

Description. Shell tiny (mean diameter 2.66 mm), brown, discoidal with low to flat spire and relatively few rounded whorls, sutures deeply impressed; protoconch spiral, sculptured with 10-12 low, flattened, widely spaced spiral cords, teleoconch sculpture of crowded, curved radial ribs, microsculpture of microradial threads and low, broad spiral cords; umbilicus wide, V-shaped.

Remarks. *Sinployea intensa* is characterised by a spiral protoconch in which the spiral cords are relatively widely spaced and flattened (Fig. 7A). The MEQ specimens cited above are the first record of the species from the region and correspond with the southern specimens in most details except size. The MEQ specimens are larger in both mean diameter (2.46 mm cf.

2.30 mm) and mean height (1.39 mm cf. 1.13 mm) but there is not enough evidence from general shell features of the available material to identify the MEQ specimens as a new species of *Sinployea* at this stage.

Comularopa Holcroft, 2018

Comularopa Holcroft, 2018c: 16.

Type species. *Comularopa georginae* Holcroft, 2018c-by original designation.

Diagnosis. Shell tiny, brown, nautilus-like with evenly coiled whorls and a slightly sunken spire; sutures strongly impressed; protoconch sculpture spiral with 11-14 thin, moderately spaced spiral cords, teleoconch with very crowded radial ribs, umbilicus moderately wide, V-shaped.

Remarks. *Comularopa* is differentiated from *Eungellaropa* gen. nov. primarily by the number of apical spiral cords (10-14 in *Comularopa* compared with 7-8 in *Eungellaropa*). Another

characteristic feature of *Comularopa* are the strongly impressed, almost furrowed sutures. *Sinployea intensa* also has a similar number of apical cords but these are broadly flattened compared with the crisp, raised spiral cords of *Comularopa*.

***Comularopa wendyae* sp. nov.**
(Figs 6C, D; 7C, D)

Etymology. Named for Wendy Dick, sister of one of the authors (LH).

Preferred Common name. Wendy's Pinwheel Snail.

Material examined. Holotype. AMSC340763, RC, Eungella Range, 50 miles W of Mackay, MEQ, 21° 04' S, 148° 36' E, coll. L. Price, ix.1957. Height of shell 1.48 mm, diameter 2.87 mm, width of umbilicus 0.98 mm, D/U 2.92, H/D 0.51, whorls 4.000.

Diagnosis. Shell tiny, brown, nautiliform with evenly coiled whorls and a slightly sunken spire; sutures strongly impressed; protoconch spiral comprising 11-14 thin, evenly spaced spiral cords; teleoconch with crowded radial ribs, 76 on the first whorl; umbilicus moderately wide, V-shaped.

Description. Shell tiny, brown, nautiliform, whorls slightly shouldered above and rounded below the periphery with a sunken spire, whorls 4, sutures strongly impressed; diameter of shell 2.87, height 1.48 mm, H/D 0.51; protoconch flat, 1.5 whorls, diameter 570 µm, spiral with 11-12 thin widely and evenly spaced spiral cords; teleoconch with crowded radial ribs, 76 on the first whorl; microsculpture of prominent microradial threads and low microspiral cords that buttress the microradial threads and form small beads at their intersection; aperture ovately lunate; umbilicus wide V-shaped, diameter 0.98 mm, D/U 2.92. Based on 1 measured specimen (AMSC340763).

Distribution and habitat. Clarke Range (=Eungella Range), west of Mackay, MEQ; presumably in rainforest under logs.

Remarks. *Comularopa wendyae* sp. nov. is distinguished from all other MEQ nautiliform charopids hitherto recorded by the combination of tiny shell with evenly coiled whorls, strongly impressed sutures (Fig. 6C) and protoconch

sculpture of 11-12 widely spaced spiral cords (Fig. 7C). *C. wendyae* differs from *C. georginae* by having a larger shell with fewer radial ribs on the teleoconch (76 in the former compared with 132 in the latter). In general shell features *C. wendyae* resembles both *Eungellaropa crediton* sp. nov. and *Sinployea intensa*. *E. crediton* has fewer apical spiral cords, rounded whorls and an elevated spire. *S. intensa* has a similar number of apical cords but these are flattened and broad. Holcroft (2018b) listed this specimen of *S. wendyae* among a number of specimens identified as *S. intensa*.

***Eungellaropa* gen. nov.**

Type species. *Eungellaropa crediton* sp. nov.

Etymology. For the township of Eungella; and a contraction of Charopa.

Diagnosis. Shell tiny, creamy beige to brown, discoidal with evenly coiled, rounded whorls and a slightly raised spire; protoconch spiral with 7-9 thin, high spiral cords; teleoconch with crowded radial ribs, microsculpture of prominent microradial threads and numerous, low microspiral cords forming small beads at their intersection; umbilicus moderately wide, V-shaped.

Remarks. *Eungellaropa* gen. nov. differs from *Comularopa* which also has a spiral protoconch by having a larger shell with fewer, more widely spaced spiral cords on the protoconch (7-8 in *Eungellaropa* compared with 10-14 in *Comularopa*). *Eungellaropa* has rounded whorls with a slightly raised spire in contrast to a shell with shouldered whorls and depressed spire in *Comularopa*. The difference in apical whorl numbers is the primary character for generic separation but the coiling pattern and general shell shape also distinguish *Eungellaropa* from *Comularopa*.

***Eungellaropa crediton* sp. nov.**
(Figs 6E, F; 7E, F)

Etymology. For the locality of Crediton.

Preferred Common name. Eungella Pinwheel Snail.

Material examined. All MEQ. Holotype. QMMO85086, RC, Eungella NP, off Eungella Dam Rd, rainforest,



FIG. 6. A-B, *Sinployea intensa*, AMSC63769, Byron Bay, NENSW. A, apical view; B, umbilical view. C-D, *Comularopa wendyae* sp. nov. AMSC340763, holotype, Eungella Range, MEQ. C, apical view; D, umbilical view. E-F, *Eungellaropa crediton* gen. et sp. nov., QMMO85086, holotype, Eungella Dam Rd, MEQ. E, apical view; F, umbilical view. A-B, E-F: scale lines = 0.5 mm; C-D: scale lines = 1 mm.

21.143°S, 148.497°E, 800 m site 2 (rep 1), litter, 766 m, coll. C.Burwell, C.Gely, 18.iii.2014. Height of shell 0.82 mm, diameter 1.56 mm, width of umbilicus 0.49 mm, D/U 3.17, H/D 0.53, whorls 3.375.

Paratypes. QMMO9724, 5 subadults RC, Crediton Ck, Eungella NP, 21°11' S, 148°32' E, 850 m, coll. M. Bishop, xi.1976.

Other material. QMMO59647, 3 juvenile RC, Diggings Rd, Eungella NP, 21°9' S, 148°29' E, coll. J. Stanisic, 8.vii.1982; QMMO85096, 1 juvenile RC, Eungella NP, Finch Hatton Gorge, rainforest, 21.062°S, 148.636°E, 400 m site 1 (rep 2), litter, 371 m, coll. C.Burwell, 16.iii.2014.

Diagnosis. As for genus.

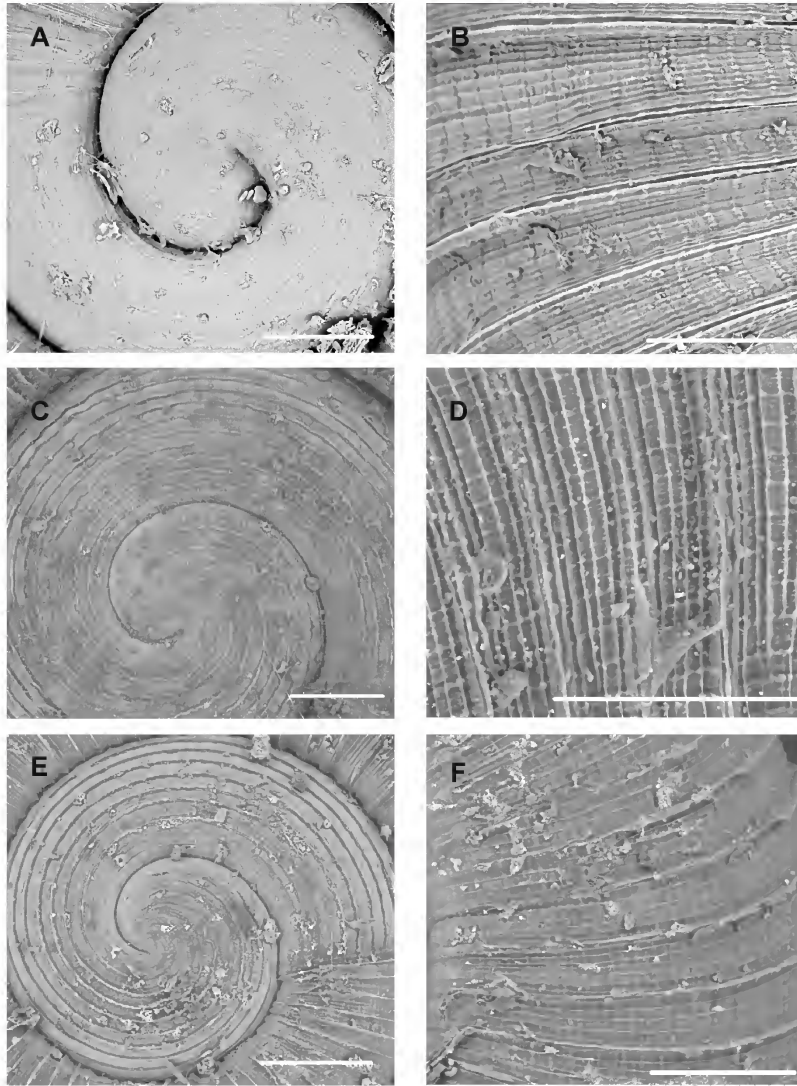


FIG. 7. A-B, *Sinployea intensa*, QMMO13475, Mackay-Seaforth Road, MEQ. A, protoconch showing flattened spiral cords; B, teleoconch showing broad spiral cords and elongate beading. C-D, *Comularopa wendyae* sp. nov. AMSC340763, holotype, Eungella Range, MEQ. C, protoconch showing slightly wavy spiral cords; D, teleoconch showing narrow spiral cords buttressing microradial threads and associated beading. E-F, *Eungella crediton* gen. et sp. nov. QMMO59647, Diggings Rd, Eungella, MEQ. E, protoconch showing well-spaced, high spiral cords; F, teleoconch showing bladed major ribs and microsculpture with low, broad spiral cords. Scale bars = 100µm.

Description. Shell tiny, golden-brown, discoidal, with rounded whorls and a slightly evert spire, whorls 3.0-3.375, sutures moderately impressed; diameter of shell 1.48-1.56 mm (mean 1.43 mm), height 0.82 mm, H/D 0.53-0.56 (mean 0.54).

Protoconch flat, 1.5 whorls, diameter 410 µm, sculpture spiral with 7-8 thin, high spiral cords; teleoconch with crowded radial ribs, 54-64 (mean 59) on the first whorl; microsculpture of prominent microradial threads over numerous,

low microspiral cords forming small beads at their intersection; aperture ovately lunate; umbilicus wide V-shaped, diameter 0.49–0.57 mm (mean 0.53 mm), D/U 2.57–3.17 (mean 2.87). Based on 2 measured specimens (QMMO85086, QMMO9724).

Distribution and habitat. Eungella NP (Crediton, Finch Hatton Gorge, Diggings Rd), MEQ; in moist humid rainforest living under logs.

Remarks. *Eungellaropa crediton* sp. nov. can be distinguished from the sympatric *Comularopa georginae* by having a smaller, golden-brown shell with rounded rather than shouldered whorls, a slightly raised spire (depressed in the latter), fewer more widely spaced spiral cords (Fig. 7E) and more widely spaced teleoconch ribbing. Shell diameter, height and umbilical width are much smaller than that of *C. georginae* which has a nautiloid shell with a much wider almost U-shaped umbilicus.

Amfractaropa Holcroft, 2018

Amfractaropa Holcroft, 2018c: 15.

Type species. *Amfractaropa bretti* Holcroft, 2018c-by original designation.

Diagnosis. Shell tiny, discoidal, nautiliform with a slightly sunken spire; protoconch spiral, of 1.75 whorls with broad spiral cords initially and broad radial ridges only appearing after 1.25 whorls; teleoconch with very crowded radial ribs, umbilicus wide, V to U-shaped.

Amfractaropa southpercyensis sp. nov. (Fig. 8A–D)

Etymology. Named for South Percy Island.

Preferred Common name. South Percy Pinwheel Snail.

Material examined. Holotype. QMMO77210, South Percy I., lagoon area, SEQ, 21°46'S, 150°20'E, eucalypt forest, coll. D. Cook, H. Janetzki, 26.xi.1992. Diameter 4.18 mm, height 2.21 mm, width of umbilicus 0.57 mm, H/D 0.53, D/U 3.64, number of whorls 4.375.

Diagnosis. Shell tiny, brown, discoidal, nautiliform with a slightly sunken spire; protoconch spiral comprising low spiral cords initially giving rise to bold radial ribs on the last quarter of the protoconch; teleoconch with crowded radial ribs, 64 on the first whorl; umbilicus wide U-shaped.

Description. Shell tiny, brown, discoidal, nautiliform with a slightly sunken spire; whorls 4.375, sutures moderately impressed; diameter of shell 4.18 mm, height 2.21 mm, H/D 0.53. Protoconch flat of 1.75 whorls, sculpture spiral with low spiral cords initially giving rise to bold radial ribs toward the protoconch-teleoconch boundary; teleoconch with crowded radial ribs, 64 on the first whorl; microsculpture of microradial threads and very low spiral cords buttressing against the radial threads and forming a small bead at their intersection; aperture ovately lunate; umbilicus wide U-shaped, diameter 0.57 mm, D/U 3.64. Based on 1 adult specimen (QMMO77210).

Distribution and habitat. Known only from South Percy Island, MEQ; living in eucalypt woodland presumably under logs and rocks.

Remarks. *Amfractaropa southpercyensis* sp. nov. is placed in *Amfractaropa* on the basis of protoconch sculpture consisting of early spiral cords followed by dominant radial ribs only on the last quarter of the longer than normal protoconch (Fig. 8D). *Amfractaropa southpercyensis* differs from the type of the genus, *A. bretti* Holcroft, 2018 by being larger and having fewer radial ribs on the teleoconch. *Amfractaropa southpercyensis* is broadly similar to *Whitcochlea iuloidea* (Forbes, 1851) in having a large, brown shell with similar shell height, umbilical width and apertural height. However it can be readily distinguished from *W. iuloidea* by the combination of protoconch sculpture featuring spiral cords initially and dominant radials on the latter third of the protoconch (= bimodal *sensu* Hyman & Stanisic, 2005: 292) compared with a singular pattern of dominant crowded spirals over low radial ribs in *W. iuloidea*. *Amfractaropa southpercyensis* also has much denser radial ribbing on the teleoconch (mean 51 ribs on the third quarter of body whorl as opposed to an average of 25 on the third quarter of the body whorl of *W. iuloidea*). *Amfractaropa southpercyensis* represents the only charopid thus far recorded from the Northumberland Group of islands.

A 'bimodal' protoconch is also present in the southern *Diphyoropa* Hyman & Stanisic,

2005 and was originally documented in the Sydney Basin *D. saturni* (Cox, 1868) by Hyman & Stanislac (2005). However, *Amfractaropa* differs from *Diphyoropa* in the structure and abundance of the spiral cords which are more numerous, less bold and more evenly spaced in the former than those of *Diphyoropa*. Bimodal protoconch sculpture is also a feature of many putative undescribed species from SEQ (Stanislac unpub.). Whether these belong in the current genus and thus extending its distribution significantly or to *Diphyoropa* is open to future investigation.

Isolderopa Stanislac, 2010

Isolderopa Stanislac, 2010 in Stanislac *et al.*, 2010: 260; Holcroft 2018d: 94.

Type species. *Isolderopa iangallowayi* Stanislac, 2010-by original designation.

Diagnosis. Shell minute to tiny, golden-brown to brown, with a depressed to very depressed, rarely flat spire, whorls numerous and very tightly coiled; protoconch sculpture finely cancellate consisting of 12-17 scalloped, fine, crisp, crowded spiral cords and widely spaced, strong radial ribs; teleoconch sculpture of densely crowded radial ribs, microsculpture of microradial threads and low spiral cords; apertural barriers usually present, umbilicus wide V-shaped to wide cup-shaped.

Remarks. The combination of a strongly sunken spire with more prominent apical spiral cords, numerous tightly coiled whorls and apertural barriers separate *Isolderopa* from *Tristanoropa* gen. nov. The species described below has a flat spire but in all other respects conforms to the *Isolderopa* plan.

Isolderopa gloucester sp. nov. (Fig. 8E-F)

Etymology. For Gloucester Island, MEQ.

Preferred Common name. Gloucester Island Pinwheel Snail.

Material examined. Holotype. QMMO71737, RC, Gloucester I., E of Bowen, MEQ, sevt, 20°00'44" S, 148°27'03" E, in litter, coll. J. Stanislac, G. Ingram, 1.x.2002. Height of shell 0.82 mm, diameter 1.39 mm,

width of umbilicus 0.57 mm, D/U 2.43, H/D 0.59, whorls 4.125.

Diagnosis. Shell minute, discoidal with numerous tightly coiled whorls and a flat to slightly raised spire; protoconch finely cancellate sculptured with scalloped, crowded spiral cords and low radial ribs forming a web-like pattern; teleoconch with numerous, extremely crowded radial ribs; three vertical palatal barriers present in aperture; umbilicus wide, cup-shaped.

Description. Shell minute, golden brown, discoidal, with a flat to slightly raised spire; whorls 4.125, sutures moderately impressed; diameter of shell 1.39 mm, height 0.82 mm; H/D 0.59, protoconch diameter 410 µm. Protoconch of 1.5 whorls, finely cancellate comprising thin, numerous scalloped spiral cords and low radial ribs forming a web-like pattern; teleoconch with extremely crowded radial ribs, 121 on the first whorl; microsculpture of microradial threads and numerous, low, prominent microspiral cords rising over the microradials forming a short bead at their intersection; aperture ovately lunate with three vertical palatal barriers and three basal barriers; umbilicus open, wide cup-shaped, diameter 0.59, D/U 2.43. Based on 1 measured adult specimen (QMMO71737).

Distribution and habitat. Gloucester I., MEQ; in vine thicket, found in litter.

Remarks. *Isolderopa gloucester* sp. nov. is distinguished from most of its congeners by the combination of flat to slightly raised spire (Fig. 8E) and extremely crowded radial ribs on the teleoconch and in having four palatal and four basal barriers (Fig. 8F). *Isolderopa gloucester* most closely resembles *I. whitsunday* Holcroft, 2018 in having very crowded radial ribs on the teleoconch (mean 118 on first whorl) and similarly configured apertural barriers but the former has a depressed rather than flat spire and more numerous barriers (five vertical and five basal).

Tristanoropa Holcroft, 2018

Tristanoropa Holcroft, 2018d: 98.

Type species. *Tristanoropa hughesae* Holcroft, 2018d-by original designation.

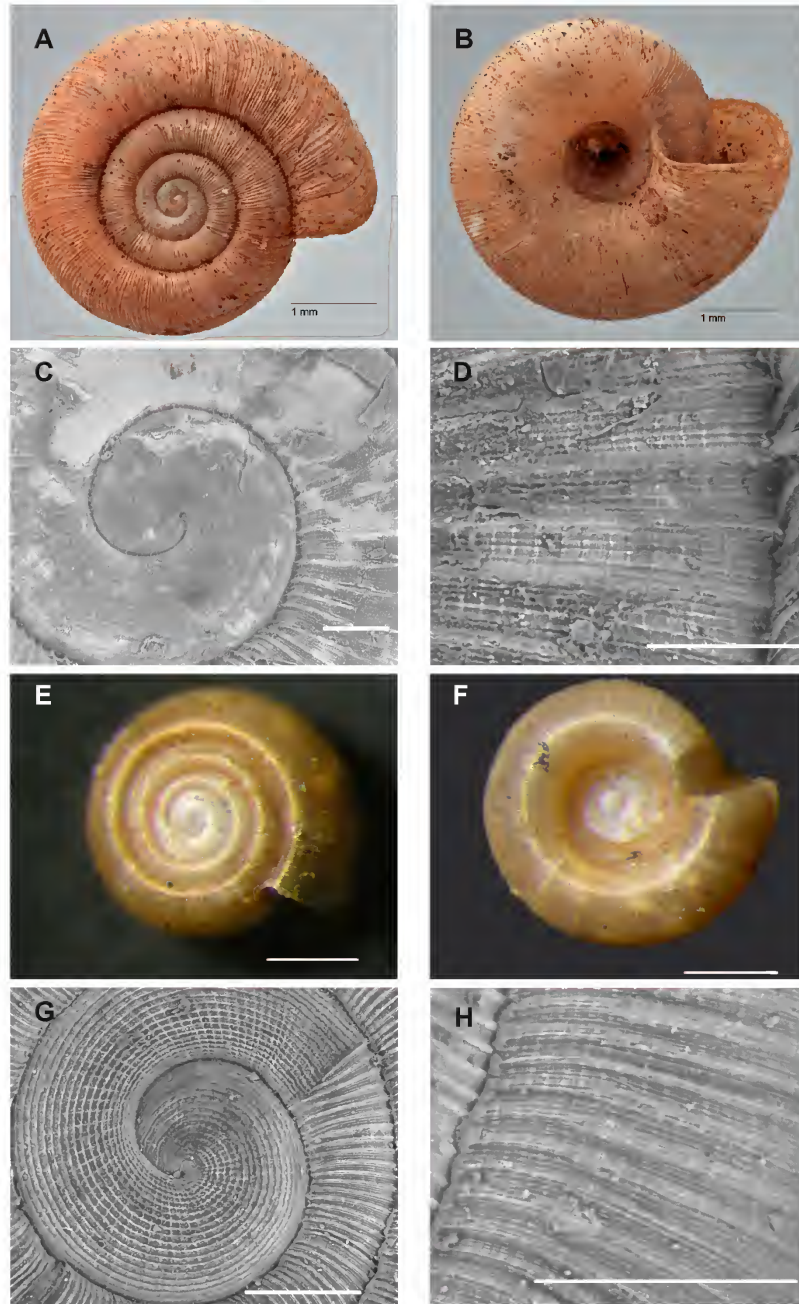


FIG. 8. **A-D**, *Amfractaropa southpercyensis* sp. nov., QMMO77210, holotype, South Percy Island, MEQ. **A**, apical view; **B**, umbilical view; **C**, protoconch showing bimodal sculpture; **D**, teleoconch showing beaded microsculpture. **E-H**, *Isolderopa gloucester* sp. nov., QMMO71737, holotype, Gloucester I., MEQ. **E**, apical view; **F**, umbilical view with apertural barriers visible through base of shell. **G**, protoconch showing finely cancellate sculpture; **H**, teleoconch showing broad spiral cords and elongate beading. **A-B**: scale lines as marked; **E-F**: scale lines = 0.5 mm; **C-D**, **G-H**: scale bars = 100µm. Images **A-B**: Geoff Thompson, QM.

Diagnosis. Shell tiny, brown, discoidal, multi-whorled with a flat to slightly raised spire, whorls numerous (> 4.5) and tightly coiled; sutures impressed; protoconch finely cancellate with 17-19 scalloped spiral cords and prominent radial ribs, teleoconch with crowded radial ribs. Apertural barriers may be present. Umbilicus wide V-shaped.

Remarks. *Tristanoropa* Holcroft, 2018 was introduced for mainland species with 4.5 or more tightly coiled whorls, wide U-shaped umbilicus, flat to slightly raised spire and a finely cancellate protoconch consisting of scalloped spiral cords and prominent radial ribbing in a web-like arrangement. The four species described below conform to this pattern in all respects and hence are assigned to *Tristanoropa* pending further study.

Tristanoropa southmolle sp. nov.
(Fig. 9A-D)

Etymology. For South Molle Island, MEQ.

Preferred Common name. South Molle Pinwheel Snail.

Material examined. Holotype. QMMO6347, South Molle I, Molle Channel, MEQ, 20°16' S, 148°50' E, coll. M. Bishop, xii.1976. Height of shell 0.66 mm, diameter 1.15 mm, width of umbilicus 0.41 mm, D/U 2.80, H/D 0.57, whorls 4.0.

Diagnosis. Shell minute, light brown, discoidal, multi-whorled with a flat spire, whorls numerous and tightly coiled; sutures impressed; protoconch finely cancellate with 17-19 scalloped spiral cords, protoconch length 1.500-1.625 whorls; teleoconch bladed with crowded radial ribs (mean 136 ribs on the first whorl); umbilicus wide V-shaped.

Description. Shell minute, light brown, discoidal with a flat spire; whorls 4.0, tightly coiled, sutures impressed; diameter of shell 1.15 mm, height 0.66 mm, H/D 0.57. Protoconch finely cancellate, flat, 1.5 whorls sculptured with scalloped, crowded spiral cords and radial ribs forming a web-like pattern; teleoconch sculpture of bladed, very crowded radial ribs 142 on the first whorl, microsculpture of microradial threads and low, broad spiral cords forming elongate beads at their intersection; a large

parietal barrier recessed about ¼ whorl back from the aperture; umbilicus wide, V-shaped, diameter 0.41 mm, D/U 2.80. Based on 1 measured adult specimens (QMMO6347).

Distribution and habitat. South Molle Island, MEQ; presumably in araucarian rainforest living in litter.

Remarks. *Tristanoropa southmolle* sp.nov. has a similar shell morphology and coiling pattern to *T. hughesae* and *T. conwayensis* Holcroft, 2018 but has a protoconch with radial rib spacing of about 5 µm as compared to the 10 µm in the previously assigned species. However, the scalloped cancellate protoconch pattern (Fig. 9C) is entirely comparable with that of *T. hughesae* and *T. conwayensis*. Hence, the species is placed in *Tristanoropa* pending further study. *T. southmolle* is distinguished from *T. conwayensis* from the Conway Range on the adjacent mainland by having a smaller shell diameter, a larger H/D ratio, much more crowded teleoconch ribbing and in possessing a parietal barrier.

Tristanoropa jaxut sp. nov.
(Figs 10A, B; 11A, B)

Etymology. Named for the Jaxut State Forest, MEQ.

Preferred Common name. Jaxut Pinwheel Snail.

Material examined. Holotype. QMMO86632, Jaxut SF, via Proserpine, MEQ, 20°48' S, 148°31' E, litter, coll. G. Annabell, 20.iv.1989. Height of shell 1.15 mm, diameter 2.30 mm, width of umbilicus 0.82 mm, D/U 2.80, H/D 0.50, whorls 5.250.

Paratypes. 13RC, QMMO85129, same data as holotype.

Diagnosis. Shell tiny, light brown, discoidal with a slightly raised spire and tightly coiled whorls; protoconch finely cancellate sculptured with scalloped, crowded spiral cords and radial ribs forming a web-like pattern; teleoconch with moderately crowded radial ribs (68 on the first whorl); umbilicus wide V-shaped.

Description. Shell tiny, light brown, discoidal with a slightly raised spire; whorls 4.125-5.250, tightly coiled, sutures impressed; diameter of shell 2.30-2.38 mm (mean 2.34 mm), height 1.15-1.31 mm (mean 1.23 mm), H/D 0.50-0.55 (mean 0.53). Protoconch finely cancellate, 1.5 whorls with

a diameter of 410 μm , sculptured with scalloped, crowded spiral cords and radial ribs forming a web-like pattern; teleoconch sculpture of bladed, moderately crowded radial ribs, 68 on the first whorl, microsculpture of microradial threads and low, vague microspiral cords; umbilicus wide, V-shaped, diameter 0.82 mm, D/U 2.80-2.90 (mean 2.85). Based on 2 measured adult specimens (QMMO86632, QMMO85129).

Distribution and habitat. Jaxut State Forest, SW of Proserpine, MEQ; vine forest found in litter.

Remarks. *Tristanoropa jaxut* sp. nov. resembles *T. summerae* sp. nov. but has a larger shell with wider umbilicus and more widely spaced radial ribs on the teleoconch. Presently known only from the Jaxut State Forest, MEQ.

Tristanoropa summerae sp. nov.
(Figs 10C, D; 11C, D)

Etymology. Named for the grand-daughter of one of the authors (JS).

Preferred Common name. Summer's Pinwheel Snail.

Material examined. Holotype. QMMO86634, St Helens Beach, at northern end, NE Mackay, MEQ, 20° 49' 34"S, 148° 50' 13" E, litter, coll. G. Annabell, 21.iv.1984. Height of shell 1.23 mm, diameter 2.05 mm, width of umbilicus 0.82 mm, D/U 2.50, H/D 0.60, whorls 5.625.

Paratypes. QMMO85135, 5RC, same data as holotype.

Other Material examined. QMMO85134, 1RC, St Helens Beach, at northern end, NE Mackay, MEQ, 20° 49' 34"S, 148° 50' 13" E, litter, coll. G. Annabell, 21.iv.1984; QMMO85144, 3RC, Cathu State Forest near O'Connell River, MEQ, 20° 49' S, 148° 36' E, litter, coll. G. Annabell, 10.iv.1982.

Diagnosis. Shell tiny, light brown, discoidal with a slightly raised spire and tightly coiled whorls; protoconch finely cancellate sculptured with scalloped, crowded spiral cords and radial ribs forming a web-like pattern; teleoconch with numerous, crowded radial ribs (mean 105 ribs on the first whorl) and vague microspiral cords; umbilicus wide V-shaped.

Description. Shell tiny, light brown, discoidal with a slightly raised spire; whorls 4.875-5.625, tightly coiled, sutures impressed; diameter of shell 1.80-2.05 mm (mean 1.91 mm), height

0.98-1.23 mm (mean 1.09 mm), H/D 0.55-0.60 (mean 0.57). Protoconch finely cancellate, 1.5 whorls with a diameter of 410 μm , sculptured with scalloped, crowded spiral cords and radial ribs forming a web-like pattern; teleoconch sculpture of bladed, very crowded radial ribs 104-105 (mean 105) on the first whorl, microsculpture of microradial threads and vague microspiral cords; umbilicus wide, V-shaped, diameter 0.66-0.82 mm (mean 0.71 mm), D/U 2.50-2.88 (mean 2.72). Based on 3 measured adult specimens (QMMO85134, QMMO85135, QMMO85144).

Distribution and habitat. St Helens Beach and Cathu State Forest, MEQ; in vine forest living under logs.

Remarks. *Tristanoropa summerae* sp. nov. differs from *T. hughesae* in having a slightly more elevated spire, less dense radial ribbing and barely visible microspiral cords on the teleoconch (Fig. 11D). In having a slightly raised spire *T. summerae* resembles *T. jaxut* sp. nov. but has a smaller shell, finer teleoconch sculpture and smaller umbilicus.

Tristanoropa hazelwood sp. nov.
(Figs 10E, F; 11E, F)

Etymology. Named for Hazelwood Creek Gorge, MEQ.

Preferred Common name. Hazelwood Pinwheel Snail.

Material examined. Holotype. QMMO85342, Hazelwood Creek, Lizzie Creek Rd, via Eungella Dam at pipeline crossing, MEQ, 21° 10' S, 148° 22' E, sevt, on banks under rocks, coll. J. Stanisic, L. Holcroft, 18.xi.2016. Height of shell 1.48 mm, diameter 2.87 mm, width of umbilicus 1.07 mm, D/U 2.54, H/D 0.58, whorls 4.625.

Diagnosis. Shell tiny, discoidal with numerous tightly coiled whorls; protoconch finely cancellate sculptured with scalloped, crowded spiral cords and radial ribs forming a web-like pattern; teleoconch with numerous, moderately crowded radial ribs (49 on the first whorl); umbilicus wide, V-shaped.

Description. Shell tiny, brown, discoidal, multiwhorled with a flat spire; whorls 5, sutures moderately impressed; diameter of shell 2.21 mm, height 1.23 mm; H/D 0.56. Protoconch of

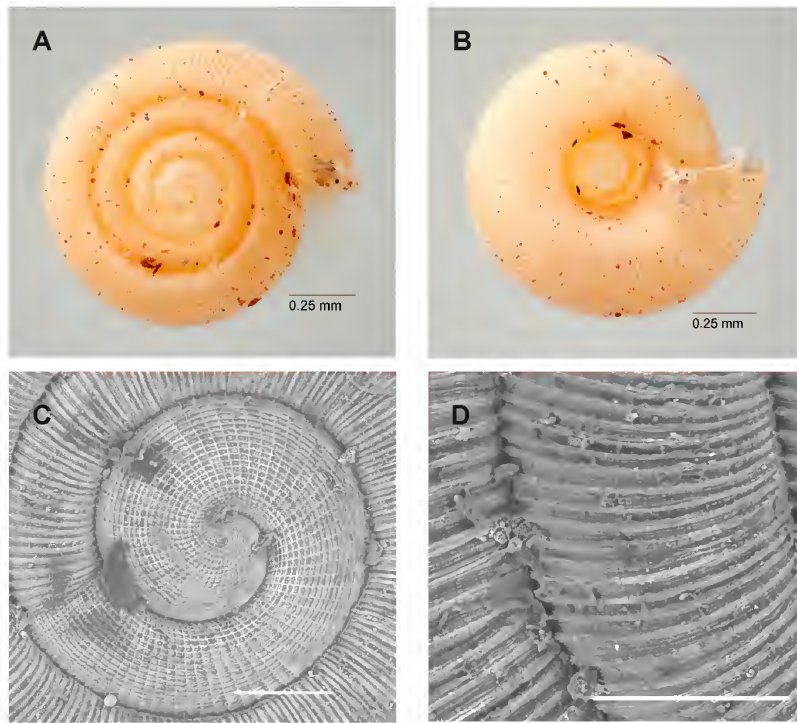


FIG. 9. *Tristanoropa southmolle* sp. nov., QMMO6347, holotype, South Molle I., MEQ. A, apical view; B, umbilical view; C, protoconch showing finely cancellate sculpture; D, teleoconch showing broad spiral cords and elongate beading. A-B: scale lines as marked; C-D: scale bars = 100μm. Images A-B: Geoff Thompson, QM.

1.625 whorls, diameter 410 μm, sculpture finely cancellate with thin, numerous spiral cords and radial ribs in a web-like pattern; teleoconch with moderately crowded radial ribs, 49 on the first whorl; microsculpture of microradial threads and numerous, low, prominent microspiral cords rising over the microradials forming a short bead at their intersection; aperture ovately lunate; umbilicus wide, V-shaped, diameter 0.82, D/U 2.70. Based on 1 measured adult specimen (QMMO85342).

Distribution and habitat. Hazelwood Creek gorge, Eungella Dam environs, MEQ; in vine thicket, found in litter under rocks.

Remarks. *Tristanoropa hazelwood* sp. nov. from Hazelwood Creek Gorge shares a multi-whorled coiling pattern similar, scalloped finely cancellate web-like protoconch and open V-shaped umbilicus with other *Tristanoropa* species but can be separated from its congeners by the

larger sized shell and having a much smaller number of ribs on the teleoconch.

PUTATIVE MEQ CHAROPID SPECIES NOT DESCRIBED AT THIS TIME

The following putative species are represented by juvenile or damaged shells and fragments that cannot be designated as holotypes for description. They have been identified as new species by their distinctive shell morphology which separates them from other MEQ charopids thus far described. Several probably represent new genera. These species will represent significant future additions to the charopid fauna of MEQ once formally described.

Comularopa Holcroft, 2018

Type species. *Comularopa georginae* Holcroft, 2018c-by original designation.

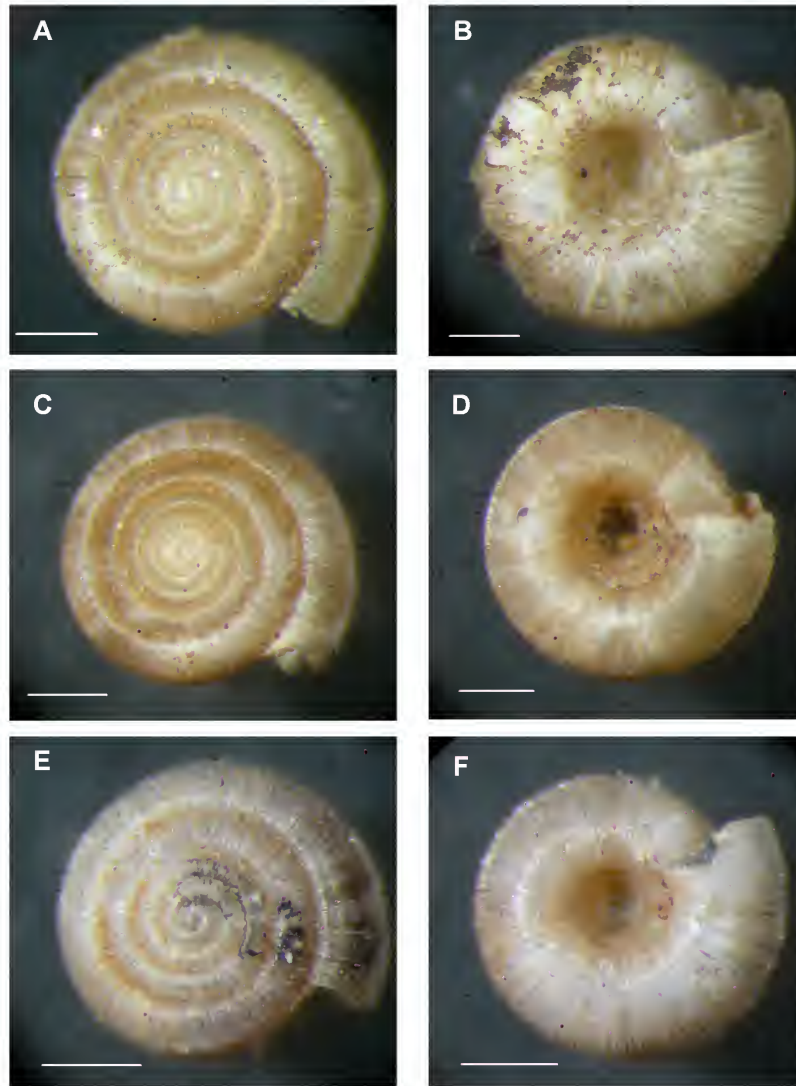


FIG. 10. A-B, *Tristanoropa jaxut* sp. nov., QMMO86632, holotype, Jaxut SF, MEQ. A, apical view; B, umbilical view. C-D, *Tristanoropa summerae* sp. nov., QMMO86634, holotype, St Helen's Beach, MEQ. C, apical view; D, umbilical view. E-F, *Tristanoropa hazelwood* sp. nov., QMMO85342, holotype, Hazelwood Ck, MEQ. E, apical view; F, umbilical view. Scale lines = 0.5 mm.

***Comularopa* sp.**
(Fig. 12A-D)

Material examined. QMMO50890, 1 juvenile RC, Eungella NP, MEQ, 20°53' S, 148°35' E, coll. ANZSES, 25.xii.1993; QMMO85095, 1 juvenile RC, Eungella NP, Mt Dalrymple, MEQ, 21.026°S, 148.638°E, 1200 m site 4, 1225 m, rainforest, litter, coll. A. Nakamura, E. Leach, 2-12.iv.2014; QMMO86633, 1

subadult RC, Dalrymple Heights, Eungella NP, MEQ, 20° 02' S, 148° 35', nvf, coll. M. J. Bishop, xi.1976.

Remarks. The above three lots from Mt Dalrymple contain juvenile specimens with only one adult whorl. Protoconch sculpture is spiral with 10-12 raised cords present (Fig. 12B) and rib counts on the first adult whorl are approximately 120-130. Microsculpture

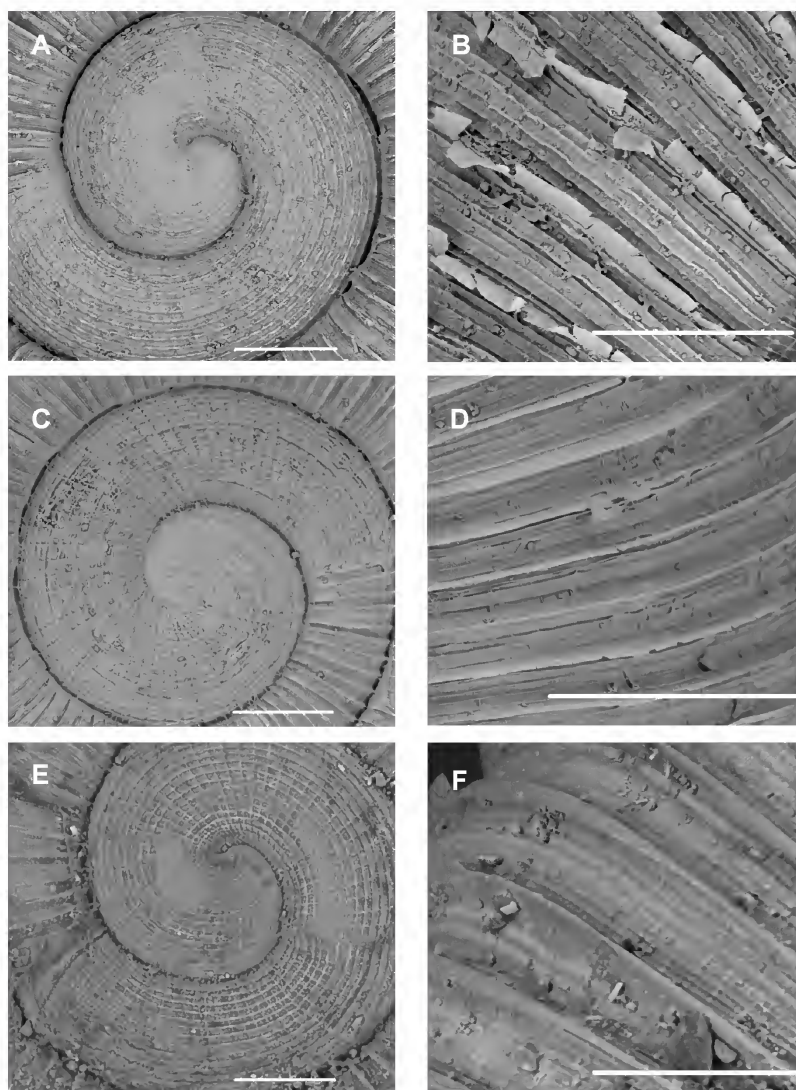


FIG. 11. A-B, *Tristanoropa jaxut* sp. nov., QMMO86632, holotype, Jaxut SF, MEQ; A, protoconch showing scalloped spiral cords; B, teleoconch showing bladed radial ribs and interstitial microradial threads. C-D, *Tristanoropa sumnerae* sp. nov., QMMO86634, holotype, St Helen's Beach, MEQ; C, protoconch showing finely cancellate sculpture; D, teleoconch showing bladed radial ribs and interstitial microradial threads. E-F, *Tristanoropa hazelwood* sp. nov., QMMO85342, holotype, Hazelwood Ck, MEQ. protoconch showing finely cancellate sculpture; D, teleoconch showing bladed radial ribs, low interstitial microradial threads and beading. Scale bars = 100µm.

consists of microradial threads and prominent, crowded, low microspiral cords forming buttresses and beads at their intersection. The specimens bear a close resemblance to *C. georginae* Holcroft, 2018 previously known only from the Crediton area, Eungella NP. The

one conflicting character in these specimens with those from Crediton is the intense spiral cording on the teleoconch (readily visible with an optical microscope) which is not present in *C. georginae* from Crediton. This could be local populational variation or it could indicate

a new species of *Comularopa*. Additional collecting, particularly on the higher elevations of Mt Dalrymple, is recommended in order to obtain adult specimens. Additional specimens of *C. georginae* from Crediton would also be helpful in resolving this issue.

Charopid MQ 48

(Fig. 12E-F)

Material examined. QMMO75828, 2 subadults RC, SW Sarina, c. 0.6 km SE Blue Mts, MEQ, 21°36' S, 148°58' E, coll., QM Party, 4.x.1999.

Distribution and habitat. Hitherto known only from the Blue Mountains area, MEQ; in dry rainforest found in litter.

Remarks. Charopid MQ 48 is represented by 2 subadult shells the largest of which is a damaged shell with diameter of 2.59 mm. The shell is horn-grey in colour with reddish brown flammulations, depressedly turbinate with a low spire and rounded whorls. The protoconch is sculptured with extremely crowded, broad and curved radial ridges and very low and very broad spiral cords only present towards the outer edge of the protoconch whorls, the radials and spirals fused thereby causing a pitted appearance; teleoconch sculpture consists of extremely crowded and strongly bladed radial ribs and a microsculpture of very low spiral cords, continuous on the base. The umbilicus is very narrow U-shaped almost pinhole. In general shell features the specimen bears some resemblance to species of *Ngairaea* Stanisic, 1990 from NENSW and SEQ. However, the unusual protoconch sculpture has not been seen in any of the charopids described to date and would indicate allocation to a new genus. Additional adult specimens are required to affirm the identity of Charopid MQ 48.

Charopid MQ 18

(Fig. 13A, B)

Material examined. QMMO13074, 1 subadult RC (shell destroyed), Diggings Rd, Eungella NP, 21° 09' S, 148° 29' E, coll. J. Stanisic, 8.v.1982. height 1.15 mm, diameter of shell 1.64 mm, H/D 0.7, umbilical diameter 0.25 mm. D/U 6.67, number of whorls 3.125.

Distribution and habitat. Hitherto known only from Diggings Road, Eungella NP, MEQ; in rainforest found in litter.

Remarks. The specimen of Charopid MQ 18 was destroyed by ultrasonic cleaning. However the shell was examined, described and photographed prior to cleaning. The shell is cream-yellow with adhering dirt particles, subdiscoidal with 3 whorls and a low spire, the sutures are strongly impressed. Protoconch sculpture is superior radial consisting of prominent radial ribs and weak spiral cords. Teleoconch sculpture consists of very widely spaced, strongly bladed, sinuous radial ribs, 34 on the first whorl and a microsculpture consisting of numerous microradial threads and prominent, closely spaced spiral cords that rise over the microradials. The umbilicus is narrowly open, V-shaped. The general shell facies, comprising a waxy shell with dominant spiral sculpture and widely spaced radial ribs on the teleoconch, is reminiscent of some species of *Coenocharopa* Stanisic, 1990 which occur in NSW and SEQ (Stanisic 2010).

Charopid MQ 3

(Fig. 13C, D)

Material examined. QMMO50893, 1 subadult RC, Eungella NP, Urannah Ck headwaters, 20°54' S, 148°33' E, coll., ANZSES, 4.i.1994.

Distribution and habitat. Eungella NP, MEQ; in rainforest recovered from litter.

Remarks. Charopid MQ 3 is represented by one subadult shell, yellowish brown in colour, with broadly trochoidal shape and a low conical spire. The whorls are angulate and the umbilicus is narrow U-shaped. Protoconch sculpture shows traces of strongly curved radial ribs and very low spiral cords while the teleoconch sculpture is comprised of strongly curved and high-bladed radial ribs which form wing-like extensions at the whorl periphery and a microsculpture of very low, broad microspiral cords (Fig. 13D). The shell is covered with adhering dirt particles. In shell shape Charopid MQ 3 most closely resembles some of the *Coenocharopa* species from SEQ

which also include species with dirt covered shells and similar teleoconch sculpture.

Charopid MQ 34 (Fig. 13E, F)

Material examined. QMMO77454, 1 fragment RC, Mackay, WNW at Mt Blackwood, half way up south side, MEQ, 21°02'10" S, 148°57' E, 590 m, coll. QM party, 18.xi.1992.

Distribution and habitat. Known only from Mt Blackwood, MEQ; in rainforest found in litter.

Remarks. The specimen of Charopid MQ 34 comprises an extremely damaged shell with only the protoconch and a partial first whorl intact. The fragment of shell is yellowish brown, the protoconch sculpture is spiral with 7-8 high spiral cords and teleoconch sculpture consists of high, very widely spaced radial ribs. Microsculpture comprises 7-10 interstitial microradial threads that form elongate beads at their intersection with low microspirals cords. Protoconch sculpture is similar to that of *Eungella* in having 7-8 widely spaced spiral cords and high, prominent and very widely spaced teleoconch ribs. However its generic status remains uncertain and additional material is needed to determine its affinities.

Mt Blackwood (altitude 639 m) is located east of the rainforests of the higher elevations of the Clarke Range (650-1200 m) and has similar vegetation to the drier araucarian forests of Mt Dryander and the Conway Range. Land snail collecting on the mountain, which has restricted access, has been sparse and there is a strong potential for finding many more charopid species on the peak. Currently this fragment represents the only known charopid specimen from the mountain.

Charopid MQ 28 (Fig. 14A-D)

Material examined. QMMO85098, 1 subadult RC, Owens Ck, Pelion SF, MEQ, 21.062°S, 148.677°E, 600 m site 7, rainforest, litter, 621 m, coll. C.Burwell, 29.iii.2014.

Distribution and habitat. Known only from Pelion SF in Finch Hatton Gorge, Eungella NP, MEQ; in rainforest recovered from litter.

Remarks. Charopid MQ 28 is represented by a biconcave subadult shell of 3.375 whorls but is immediately distinguished from other MEQ charopids by the combination of irregularly and finely beaded protoconch sculpture (Fig. 14C) and extremely fine and densely crowded radial ribs on the teleoconch (147 on the first adult whorl). The shell has a protoconch of 1.75 whorls, very deeply depressed spire and wide saucer-shaped umbilicus. Under optical microscopy, the protoconch has the appearance of frosted glass which when viewed by SEM is comprised of numerous tiny tubercles irregularly arranged in a vaguely spiral pattern. The only protoconch sculpture of the many charopids examined to date that most closely resembles the sculpture of Charopid MQ 28 is that of *Lithocouperia kalkajaka* Stanislac, 2016 from Black Mountain, near Cooktown, NEQ (Stanislac 2016). However, *L. kalkajaka* differs significantly in having a much larger shell and protoconch with the raised tubercles in more defined spiral rows. Charopid MQ 28 is considered to represent a new genus with likely congeners either in the Border Ranges, SEQ or Wet Tropics, NEQ suggesting early isolation in the CMC.

DISCUSSION

This paper concludes the trilogy of publications documenting the charopid fauna of MEQ that was begun by Holcroft (2018c, d). The first of these publications dealt with nine relatively large *Gyrocochlea*-grade species of which four previously described species were revised and three reassigned to new genera and five were described as new in newly diagnosed genera (Holcroft 2018c). The second article covered 12 very tiny species with finely cancellate sculptures of which six previously described species were redescribed and six were newly described in new and existing genera (Holcroft 2018d). With the completion of this study, the charopid fauna of MEQ stands at 37 species with an additional six considered to be putative new species but not yet formally described bringing the total to 43 species.

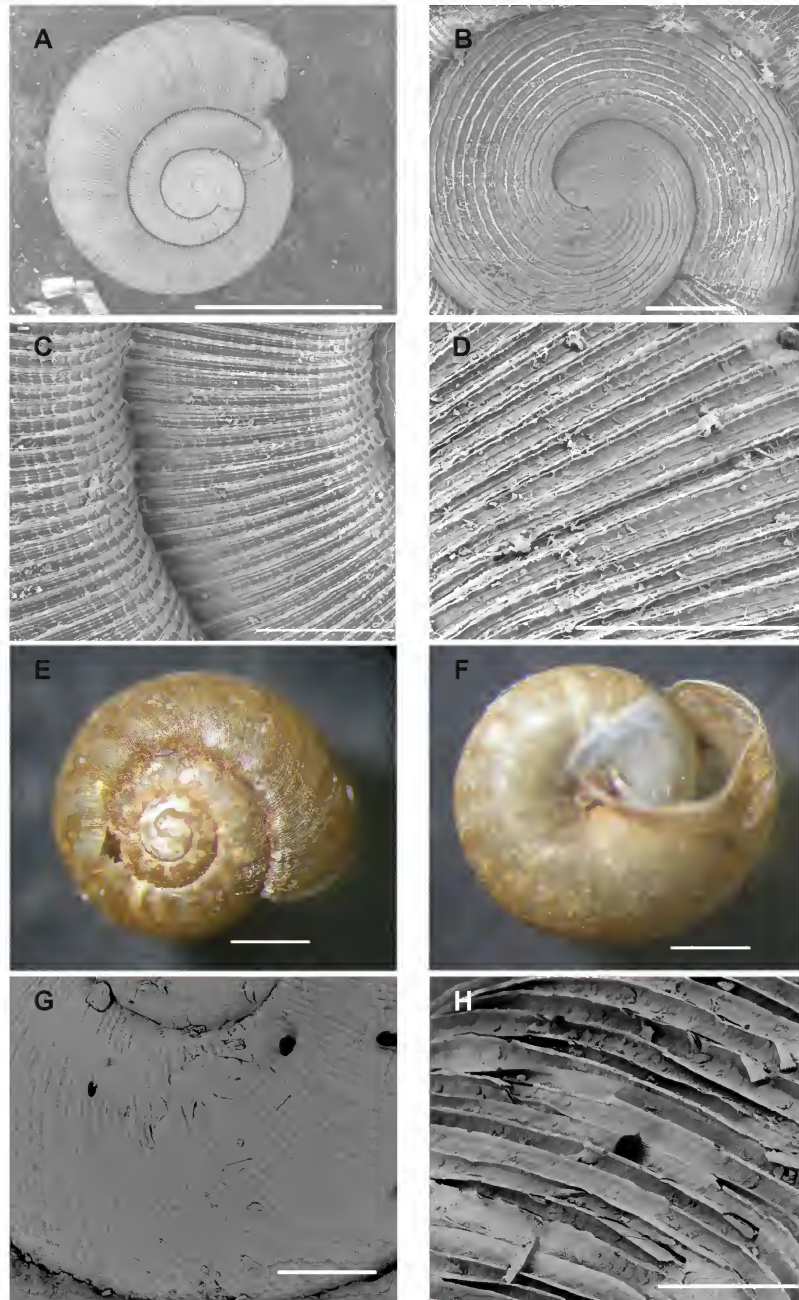


FIG. 12. A-D, *Comularopa* sp., QMMO86633, Dalrymple Hts, MEQ. A, apical view; B, protoconch showing wavy spiral cords; C-D, teleoconch sculpture. E-H, Charopid MQ48, QMMO75878, Blue Mts, MEQ; E, apical view; F, umbilical view; G, protoconch showing curved radials and pitted sculpture at outer edge; H, teleoconch showing crowded, bladed radial ribs and low, crowded microspiral cords. A-B, C-D, G, H: scale bars = 100µm; E-F: scale lines = 0.5 mm.

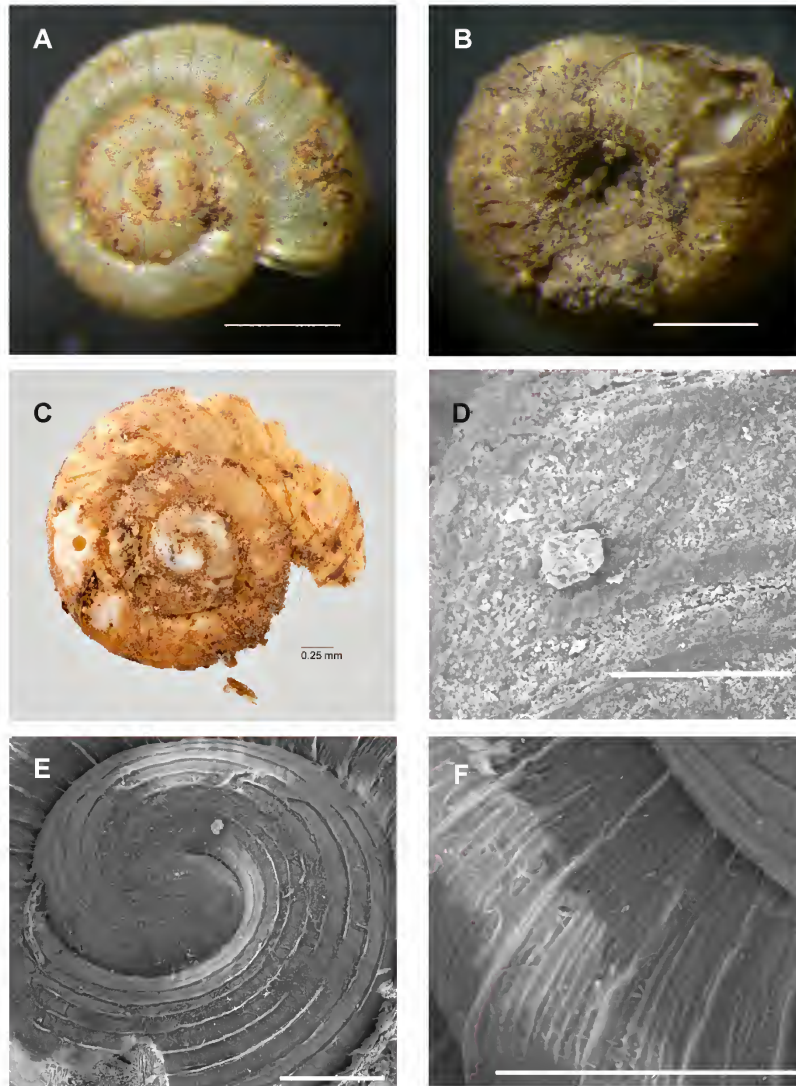


FIG. 13. A-B, Charopid MQ18, QMMO13074, Diggings Road, Eungella NP, MEQ. A, apical view; B, umbilical view. C-D, Charopid MQ3, QMMO50893, Eungella NP, MEQ; C, apical view; D, teleoconch showing low, broad spiral cords. E-F, Charopid MQ34, QMMO77454, Mt Blackwood, MEQ; C, protoconch showing widely spaced, high spiral cords; F, teleoconch sculpture of very widely spaced radial ribs and interstitial microradial threads. A-B: scale lines = 0.5 mm; C: scale line as marked; D-F: scale bars = 100µm.

Holcroft (2018c, d) dealt with mainly MEQ endemic genera and species. In contrast this study includes genera with congeners outside the Central Mackay Coast bioregion or species with more widespread distributions. Among the newly diagnosed genera in this study *Eungellaropa*, *Hirsutaropa* and *Burwellia* are identified as additional MEQ endemics.

All the charopids dealt with in the MEQ study are rainforest or dry vine thicket species and a feature of this fauna is the high number of genera represented (23) relative to species (37), many being monotypic. However, the study of the Charopidae in MEQ is only in its relative infancy despite the efforts of Holcroft (2018b). It is considered highly probable that additional

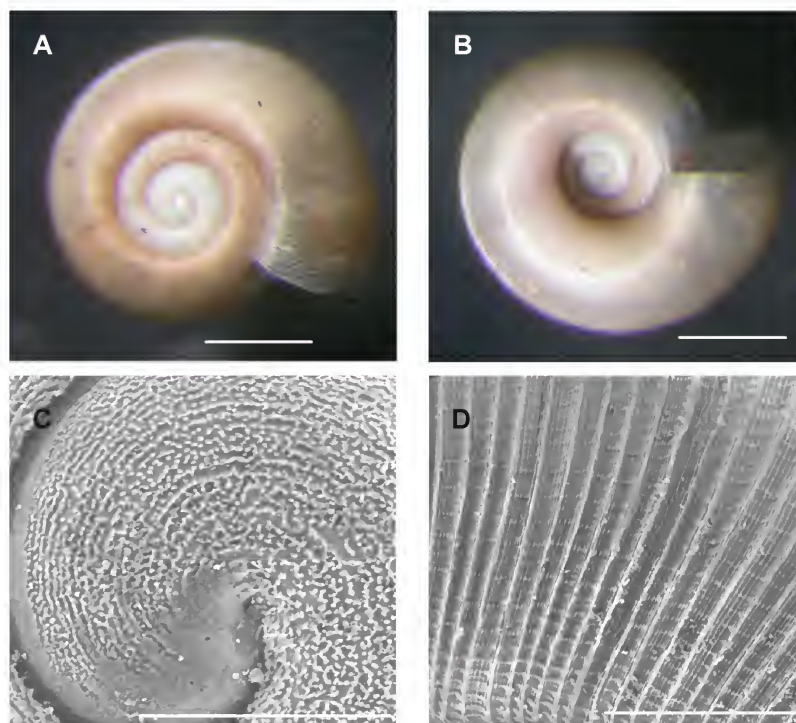


FIG. 14. A-D, Charopid MQ 28, QMMO85098, Pelion SF, Eungella NP, MEQ. **A**, apical view; **B**, umbilical view; **C**, protoconch showing vague spiral arrangement of low tubercles; **D**, teleoconch showing sculpture of very crowded radial ribs and beaded microsculpture. A-B: scale line = 0.5 mm; C-D: scale bars = 100 μ m.

targeted collecting, particularly of leaf litter in the key areas identified in that review, will result in the addition of more species to some of the genera.

Results to date have shown that only the 'finely cancellate' genera (*Pereduropa*, *Isolderopa* and *Tristanoropa*) have established significant radiations in the MEQ rainforests. Other genera show no such tendency.

Biogeographic implications. The relatively high generic diversity of the Charopidae in the MEQ rainforests is most likely the result of the initial period of species accumulation followed by large scale extinctions resulting from many episodes of climate-induced environmental sifting of mesic communities from mid-Miocene onwards (Kemp 1981). The gradual aridification of the continent since the late Tertiary (Miocene, Pliocene) resulting in the inexorable contraction of eastern

Australian rainforests would have had significant consequences for MEQ rainforests and their fauna. Climatic changes in the Quaternary were similar in amplitude to those experienced in the late Miocene and Pliocene but would have occurred in more rapid succession. Galloway & Kemp (1981) concluded that these changes must have placed considerable stress on montane and coastal environments and that the modern communities in these situations are recent phenomena consisting of biota that have survived in isolated refuges.

Winter's (1988) study of rainforest mammals of MEQ suggested that MEQ rainforests contracted to very small areas during this period whereby rainforest specialist mammals would not have survived. However, land snails do not require the same acreage of landscape in which to exist. Hence, throughout this period of mesic habitat reduction, the more robust of the charopid species would most likely have eked

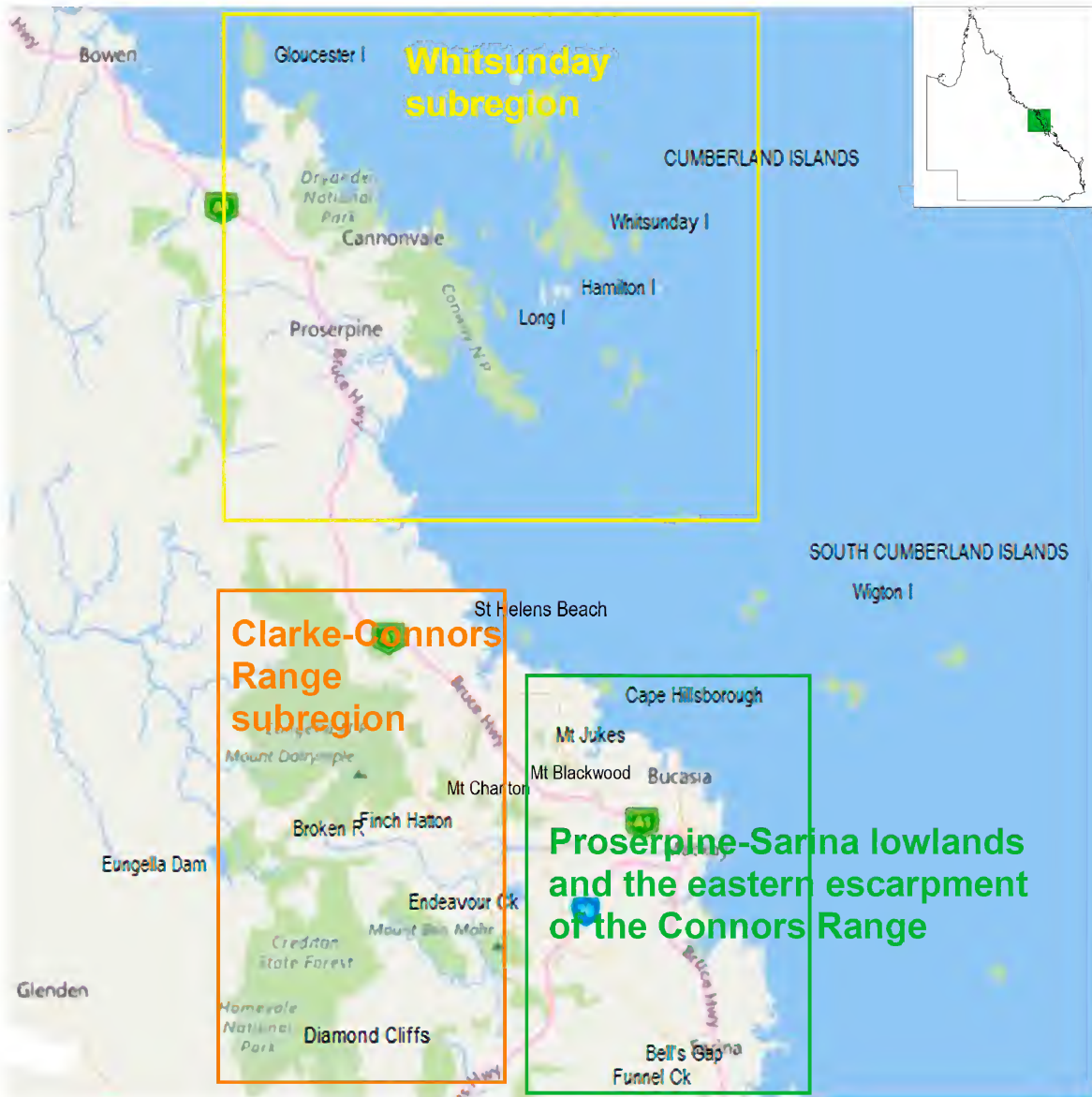


FIG. 15. Map showing major locations and collecting areas in MEQ [from Holcroft 2018d].

out an existence in arrow-head gullies, riparian habitats, small patches of drier rainforest and in scattered lithoreugia. Extinctions of less resilient species would have been widespread.

Joseph & Moritz (1993) in a study of MEQ rainforest birds provided mitochondrial evidence for the recent isolation of SEQ and

MEQ compared with the longer term isolation of NEQ rainforests from those of both SEQ and MEQ. Connections for the birds with the south would have continued through periods of climatic attrition to present day by way of smaller intervening patches of surviving drier rainforest. But it is highly unlikely that the low vagility, tiny pinwheel snails would

have recolonised MEQ rainforests from the south through this archipelago of dry vine forests once the link of continuous forest was broken. Therefore, it is logical to assume that the current charopid fauna of the Central Mackay Coast bioregion was probably molded in isolation during the many glacial episodes of the Plio-Pleistocene and 'set in stone' at the height of the last glacial.

Historical connections, with the rainforest massifs both to the south (Border Ranges) and north (Wet Tropics) probably dating to the formation of the Burdekin and St Lawrence Gaps dry corridors, are flagged by the presence of *Setomedeia janae* and *Lenwebbia marissae*. Unfortunately the support for an earlier isolation from the north versus south, as would be indicated by more affinities of the MEQ charopids with the southern taxa, is currently unavailable.

Intra-regionally the pinwheel snails provide broad evidence of persistent mesic refugia, however small, during the Plio-Pleistocene within the Clarke-Connors subregion (bioprovince) of the CMC bioregion. The monotypic genera *Burwellia*, *Eungellaropa* and *Comularopa* are endemic to higher elevations of the Clarke Range. With no known relatives outside this bioregion it can be assumed that these rainforest specialist charopid lineages either developed within refugia or as may be the case with the conchologically atypical *Burwellia staceythomsonae*, be leftover relicts of once more diverse and widespread lineages. The conchologically unusual *Hirsutaropa sarina* and Charopid MQ 48 indicate that the Blue Mountains and Funnel Creek (both riparian habitats) areas may also have been significant refugia for mesic species. The finely cancellate *Tristanoropa* has radiated extensively in the segregated patches of dry vine thicket within the CMC bioregion and may have affinities with species in similar habitat further to the south and in the Brigalow Lands bioregion to the west.

These biogeographic speculations signal the prospect of a charopid phylogeny judiciously informing our current understanding of

eastern Australian biogeography. However, a more rigorous biogeographic interpretation is contingent on a detailed study of the very large and diverse, but chiefly undescribed, charopid faunas of SEQ and NEQ currently represented and held in the collections of the Queensland Museum (Stanisic, pers. obs.).

CONCLUSIONS

Protoconch sculpture has been the basis for defining genera in this and the related studies of Holcroft (2018c, d) following on Holcroft (2018a)'s seminal investigation of eastern Australian charopid protoconchs. Holcroft's research showed that there was both a broad north-south and intra-bioregional distribution of the major protoconch sculptural configurations identified within the eastern Charopidae. The outcomes of the MEQ charopid study fully reflect this broad pattern. A high level of generic endemism within the charopids of the Central Mackay Coast bioregion is complemented by genera with more widespread connections to the north and south.

The three systematic publications emanating from the chiefly museum-based MEQ charopid study of Holcroft (2018b) have resulted in the description of 12 new genera and 24 new species from an area previously not renowned for its fauna of tiny pinwheel snails (Holcroft 2018c, d; this publication). This outcome poignantly highlights the broader taxonomic impediment facing this mega-diverse Gondwanan family in eastern Australia whereby large numbers of charopid species in museum collections await formal documentation.

ACKNOWLEDGEMENTS

The authors would like to thank Darryl Potter, Biodiversity Collection Manager, Queensland Museum and Alison Miller, Collection Manager, Malacology Section, Australian Museum, Sydney for making the study material available. Thanks are also due to Geoff Thompson of the Queensland Museum's Digital Imaging Unit for a number of the high resolution images used in this study. This study is based on a Master of Philosophy thesis conducted through

Griffith University's School of Environment and Science. The senior author would like to thank Professor Jane Hughes, Griffith University and Dr Chris Burwell, Queensland Museum for their valuable support in that study.

LITERATURE CITED

- Forbes, E. 1851. On the Mollusca collected by Mr Macgillivray during the voyage of the Rattlesnake. Pp. 360-386 *In*, Macgillivray, J. (ed.) *Narrative of the Voyage of the H.M.S. Rattlesnake commanded by the late Captain Owen Stanley, during the years 1846-1850*, Volume 2. (T & W Boone: London).
- Galloway, R. W. & Kemp, E. M. 1981. Late Cainozoic environments in Australia. Pp. 52-80. *In*, A. Keast (ed.), *Ecological Biogeography of Australia*. (W. Junk Publishers: The Hague, Netherlands).
- Hedley, C. 1912. On some land shells collected in Queensland by Mr. Sidney W. Jackson. *Proceedings of the Linnean Society of New South Wales* **37**: 253-270. <https://doi.org/10.5962/bhl.part.22346>.
- Holcroft, L. 2018a. Protoconch sculpture as a taxonomic tool in Australian charopid systematics (Gastropoda: Eupulmonata: Charopidae). *Molluscan Research*. <https://doi.org/10.1080/13235818.2017.1409069>.
- Holcroft, L. 2018b. Elucidating the diversity of mid-eastern Queensland Pinwheel Snails (Eupulmonata: Charopidae) using aspects of shell morphology. (Unpub. Master of Philosophy thesis, Griffith University: Brisbane).
- Holcroft, L. 2018c. A revision of Gyrocochlea-grade Charopidae from mid-eastern Queensland and redescription and generic reassignment of three Gyrocochlea-grade species (Eupulmonata: Charopidae). *Memoirs of the Queensland Museum-Nature* **61**: 1-28. <https://doi.org/10.17082/j.2204-1478.61.2018.2017-14>.
- Holcroft, L. 2018d. A revision of Charopidae with a finely cancellate protoconch sculpture from mid-eastern Queensland. (Eupulmonata: Charopidae). *Memoirs of the Queensland Museum-Nature* **61**: 83-107. <https://doi.org/10.17082/j.2204-1478.61.2018.2018-09>.
- Hyman, I.T. & Stanisic, J. 2005. New charopid landsnails, chiefly from limestone outcrops in eastern New South Wales (Eupulmonata: Charopidae). *Memoirs of the Queensland Museum* **50**: 219-302.
- Iredale, T. 1933. Systematic notes on Australian land shells. *Records of the Australian Museum* **19**: 37-59. <https://doi.org/10.3853/j.0067-1975.19.1933.690>.
- Iredale, T. 1937. A basic list of the land Mollusca of Australia. *Australian Zoologist* **8**: 287-333.
- Iredale, T. 1941a. Guide to the land shells of New South Wales. Pt II. *Australian Naturalist* **10**: 262-269.
- Iredale, T. 1941b. Guide to the land shells of New South Wales. Pt III. *Australian Naturalist* **11**: 1-8.
- Joseph, L. & Moritz, C. M. 1993. Phylogeny and historical aspects of the ecology of eastern Australian scrubwrens: evidence from mitochondrial DNA. *Molecular Ecology* **2**: 161-170. <https://doi.org/10.1111/j.1365-294X.1993.tb00105.x>.
- Kemp, E. M. 1981. Tertiary paleogeography and the evolution of Australian climate. Pp. 32-49. *In*, A. Keast (ed.), *Ecological Biogeography of Australia*. (W. Junk Publishers: The Hague, Netherlands). https://doi.org/10.1007/978-94-009-8629-9_3.
- Shea, M., Colgan, D. & Stanisic, J. 2012. Systematics of the landsnail genus Gyrocochlea and relatives (Mollusca: Charopidae). *Zootaxa* **3585**: 1-109.
- Smith, B.J. 1992. Non-marine Mollusca. *In*, Houston, W.W.K. (ed.) *Zoological Catalogue of Australia*. Australian Government Publishing Service: Canberra. Vol. 8 xii 408 pp.
- Solem, A. 1983. Endodontoid land snails from Pacific Islands (Mollusca: Pulmonata: Sigmurethra). Part II. *Families Punctidae and Charopidae, Zoogeography*. (Field Museum: Chicago).
- Stanisic, J. 1990. Systematics and biogeography of eastern Australian Charopidae (Mollusca: Pulmonata) from sub-tropical rainforests. *Memoirs of the Queensland Museum* **30**: 1-241.
- Stanisic, J. 1993. *Lenwebbia paluma* sp. nov., from the Wet Tropics, northeastern Queensland (Pulmonata: Charopidae). *Memoirs of the Queensland Museum* **34**: 21-26.
- Stanisic, J., Shea, M., Potter, D. & Griffiths, O. 2010. *Australian Land Snails Volume 1: A Field Guide to Eastern Australian Species*. (Bioculture Press: Mauritius).
- Stanisic, J. 2016. Two new species of Pinwheel Snail from Queensland and a redescription and generic reassignment of Gyrocochlea myora Stanisic, 2010 (Gastropod: Eupulmonata: Charopidae). *Memoirs of the Queensland Museum-Nature* **60**: 1-12. <https://doi.org/10.17082/j.2204-1478.60.2016.2016-07>.
- Winter, J. 1988. Ecological specialization of mammals in Australian tropical and sub-tropical rainforest: refugial or ecological determinism? *Proceedings of the Ecological Society of Australia* **15**: 127-138.

Memoirs of the Queensland Museum | **Nature** **61**

© The State of Queensland, Queensland Museum 2019

PO Box 3300, South Brisbane 4101, Australia
Phone 06 7 3840 7555
Fax 06 7 3846 1226
Email qmlib@qm.qld.gov.au
Website www.qm.qld.gov.au

National Library of Australia card number
ISSN 0079-8835 Print
ISSN 2204-1478 Online

NOTE

Papers published in this volume and in all previous volumes of the *Memoirs of the Queensland Museum* may be reproduced for scientific research, individual study or other educational purposes. Properly acknowledged quotations may be made but queries regarding the republication of any papers should be addressed to the Editor in Chief. Copies of the journal can be purchased from the Queensland Museum Shop.

A Guide to Authors is displayed at the Queensland Museum web site www.qm.qld.gov.au

A Queensland Government Project
Typeset at the Queensland Museum

Current status of the genera *Karma* and *Magmellia* Wells, 2009 (Scincidae: Lygosominae: Sphenomorphini), with a morphological character to distinguish the two genera.

Glenn M. SHEA

Sydney School of Veterinary Science, B01, Faculty of Science, University of Sydney NSW 2006, Australia and Australian Museum Research Institute, Australian Museum, 1 William St, Sydney NSW 2010.

<https://doi.org/10.17082/j.2204-1478.61.2019.2018-03>

LSID urn:lsid:zoobank.org:pub:F7DDB03D-4CEE-4D6E-92A4-5E64013EE8C2

Citation: Shea, G.M. 2019. Current status of the genera *Karma* and *Magmellia* Wells, 2009 (Scincidae: Lygosominae: Sphenomorphini) with a morphological character to distinguish the two genera. *Memoirs of the Queensland Museum – Nature* 61: 187–191. ISSN 2204-1478 (Online), ISSN 0079-8835 (Print). Accepted: 24 April 2018. First published online: 24 September 2019.

ABSTRACT

Recognition and distinction of the scincid genera *Karma* and *Magmellia*, also cited in the literature under their respective junior synonyms *Silvascincus* and *Tumbunascincus*, have been largely based on genetic evidence, with only minor features of coloration reported to distinguish them. The monotypic *Magmellia* can be morphologically distinguished from the two species of *Karma* by the overlap pattern of the temporal scales (lower secondary temporal overlapping upper secondary temporal), a character state not previously reported for *Magmellia*. □ *Karma*, *Magmellia*, *Silvascincus*, *Tumbunascincus*, *Scincidae*, *Queensland*, *systematics*, *scalation*.

Wells (2009) erected the genera *Karma* and *Magmellia* for three species of medium-sized rain-forest skinks from eastern Australia, *Lygosoma murrayi* Boulenger, 1887, *Lygosoma (Hinulia) tryoni* Longman, 1918 and *Sphenomorphus luteilateralis* Covacevich & McDonald, 1980, that had previously been considered to represent a single monophyletic species group, the *Eulamprus murrayi* group (Greer 1989; Sadlier 1998; O'Connor & Moritz 2003).

The recognition of these two genera followed broader phylogenetic analyses of sequence data by Skinner (2007) that showed that the *E. murrayi* species group, though previously considered monophyletic within a polyphyletic genus *Eulamprus* (O'Connor & Moritz 2003) was paraphyletic with respect to seven other species of elongate-bodied sphenomorphin skinks that had previously been assigned to the monotypic genera *Saiphos* and *Coggeria*, and two more speciose genera, *Coeranoscincus* and *Ophioscincus*. Of the species previously

ascribed to the *Eulamprus murrayi* species group, *murrayi* was recovered as sister to the lineage consisting of *Coeranoscincus*, *Coggeria*, *Ophioscincus* and *Saiphos*, with *luteilateralis* further distant (Skinner 2007 did not include *tryoni* in his analyses). On mitochondrial data (12S rRNA, 16SrRNA, ND4 and adjacent tRNAs), *luteilateralis* was sister to *murrayi* + the other four genera, but further distant when a nuclear intron (ATP synthetase- β subunit) was included in the analysis. Skinner *et al.* (2013) added data from three more nuclear genes (*c-mos*, *LDLR* and *PTPN12*), and recovered *luteilateralis* as sister to two clades, one of *murrayi* and *tryoni*, the other of *Coeranoscincus*, *Coggeria*, *Ophioscincus* and *Saiphos*, similar to the mitochondrial tree of Skinner (2007). An outgroup relationship of *luteilateralis* to *murrayi* + and *tryoni* was also recovered by O'Connor and Moritz (2003) using the mitochondrial 16S rRNA segment, although they did not include the elongate-bodied taxa in their analysis. Pyron *et al.* (2013), using the sequence data

from the previous studies, were unable to recover a similarly paraphyletic *Eulamprus murrayi* species group, but did again identify *luteilateralis* as the sister to *murrayi* and *tryoni*, with *Saiphos*, *Coeranoscincus*, *Coggeria* and *Ophioscincus* as a single lineage that was sister to these three species. Hence, although using different genes and/or different analyses of the data, all genetic studies agreed that *luteilateralis* was outside the sister-pair of *murrayi* and *tryoni*, disagreeing as to how far distant it was placed (i.e., whether the three species represented a monophyletic group, or a paraphyletic group).

Skinner *et al.* (2013), either overlooking the previous naming of the genera *Karma* (for *murrayi* and *tryoni*) and *Magmellia* (for *luteilateralis*) by Wells (2009), or intentionally ignoring those names, following the proposal of Kaiser *et al.* (2013) to ignore post-2000 names established by Wells in his privately-published papers, created the two generic names *Silvascincus* and *Tumbunascincus* for the same two generic concepts respectively. Most recent national and regional field guides have used the generic epithets *Karma* and *Magmellia* (Cogger 2014; Wilson 2015, 2016; Wilson & Swan 2017; Swan *et al.* 2017).

The diagnoses of the two genera by both Wells (2009) and Skinner *et al.* (2013) were extremely limited. Comparison of the generic diagnoses of *Karma* and *Magmellia* by Wells (2009) reveals that they were putatively distinguished by number of midbody scales (28–36 *vs* 36–42), and relative limb length (for *Magmellia*, “well-developed pentadactyl limbs, that strongly overlap when adpressed (much more so than in *Concinnia* or *Karma*)”). The remaining character states presented are the same for both genera. However, of these purported characters, the number of midbody scales is non-diagnostic, as *Karma tryoni* has 38–42 midbody scales (Sadler 1998), and covers the range of variation observed in *Magmellia*. The claim of differences in limb length between the genera is not supported, nor are there any observations in the literature for *M. luteilateralis*. I have some data on hindlimb length for *M. luteilateralis* (hindlimb length/ snout-vent length 38.5–45.3%, mean = 41.6%, *n* = 10), which shows almost complete

overlap with *K. murrayi* (34.3–43.3%, mean = 38.7%, *n* = 13) and *K. tryoni* (36.5–44.6%, mean = 40.7%, *n* = 14) as provided by Sadler (1998). Wells (2009) did not specifically justify recognising two genera from within what he had previously considered in the same paper to be a single species group.

Similarly, the diagnoses of both *Silvascincus* and *Tumbunascincus* by Skinner *et al.* (2013) cite two shared scalation synapomorphies reported by previous authors (Greer 1989; Sadler 1998; O'Connor & Moritz 2003; Wells 2009) for the entire *murrayi* species group within *Eulamprus* in its former broad sense: the postmental scale contacting only a single infralabial on each side, and the third pair of chin shields separated by five scales, together with a third character (visceral fat bodies absent) that is true of most Australian members of the Sphenomorphini (Greer 1986), being present only in *Concinnia* and *Gnypetoscincus* (I confirm they are also present in *Nangura*, which has been recovered on genetic grounds as part of *Concinnia* (O'Connor & Moritz 2003; Skinner *et al.* 2007, 2013; Pyron *et al.*, 2013)). Hence, these three characters do not distinguish *Silvascincus* and *Tumbunascincus* from each other. A fourth diagnostic character cited for *Silvascincus*, “pale to bright yellow ventral colouration” lacked any contrasting character state for *Tumbunascincus*, and the fourth diagnostic character for *Tumbunascincus* “lateral surfaces between forelimb and hind limb bright orange with small white spots”, lacked any contrasting character state for *Silvascincus*.

While the description of *Sphenomorphus luteilateralis* by Covacevich and McDonald (1980) reports the ventral colour of preserved species as white, and a white venter is also mentioned by Wilson and Knowles (1988) and Cogger (2014), live individuals have yellow to orange bellies, more yellow in females, more orange in males and approaching the orange lateral colour (S. Eipper, pers. comm., individuals from near Mt Dalrymple). A photograph of an unsexed individual also shows a pale yellow belly (E. Budd, pers. comm.). This character therefore cannot be used as to distinguish between these two genera. The lateral colour pattern for

Magmellia (= *Tumbunascincus*) is very similar to that of *Karma* (= *Silvascincus*): both consist of numerous tiny, dark-edged pale flecks (white to blue-white) on a darker ground colour, and both possess a dark supra-axillary blotch. The main difference is in the ground colour of the flanks – more orange/yellow in *Magmellia*, and more grey/blue in *Karma*, although *K. murrayi* also possesses larger yellow spots on the dark ground.

Despite the lack of any obvious differences between the genera in the literature, there is one scalational character, not previously mentioned for either genus, that does distinguish them. In both species of *Karma* (bilaterally in 142/145 *K. murrayi* examined, and unilaterally in the other three individuals; bilaterally in all nine *K. tryoni*), the lower secondary temporal is overlapped by the upper secondary temporal, as in most skinks. However, in *Magmellia luteilateralis*, the lower secondary temporal typically overlaps the upper secondary temporal (Fig. 1). Of 24 specimens of this species examined, this state is present bilaterally in 20, and unilaterally in the remaining four. The character state is also visible in photographs of live individuals by Wilson and Knowles (1988), Ehmann (1992), Fyfe (2008), Cogger (2014), Wilson (2015), and Wilson and Swan (2017).

Greer and Shea (2003) called attention to the importance of this character in sphenomorphin skinks. Among the other genera related to *Magmellia* (based on the genetic analyses of Skinner *et al.* 2013), the lower secondary temporal scale overlaps the upper secondary temporal scale only in *Coeranoscincus reticulatus* and *Coggeria naufragus* among the ingroup taxa (lower secondary temporal overlapped by upper secondary temporal in *Saiphos*, *Ophioscincus* and *Coeranoscincus frontalis*; Greer 1983; Greer & Cogger 1985; Couper *et al.* 1996), while in the first outgroup, (*Nangura* (*Gnypetoscincus* (*Concinnia*))), it is present in *C. martini* and *C. frerei*, but not in *C. brachysoma*, *C. sokosoma*, *C. tenuis* or *C. tigrina* (Greer 1992; pers. obs. for *C. tigrina*). *Nangura* and *Gnypetoscincus* have multiple small temporal scales (Greer 1989; Covacevich *et al.* 1993), and the homologies of these are uncertain. *Concinnia amplus*, a species of

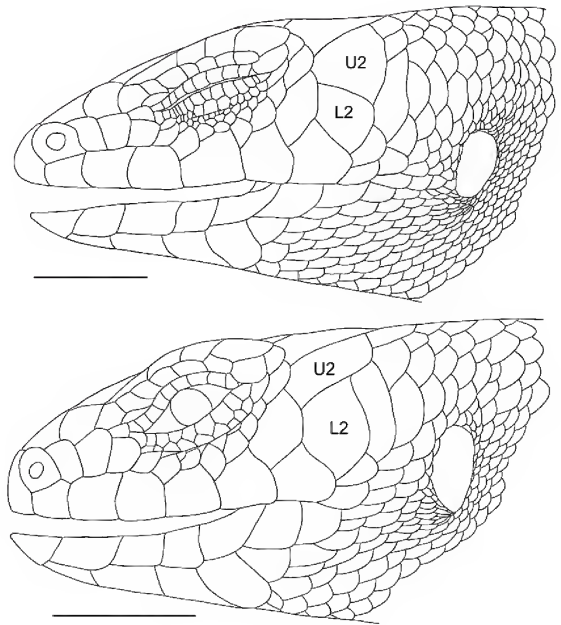


FIG. 1. Lateral views of heads of *Magmellia luteilateralis* (Australian Museum R113928) (top) and *Karma murrayi* (Australian Museum R6485, holotype of the synonym *Lygosoma* (*Hinulia*) *tenuis intermedius*) (bottom). Scale bars = 5 mm. The lower and upper secondary temporal scales are indicated by L2 and U2 respectively.

uncertain affinities to the other *Concinnia* species, with its position with respect to *Gnypetoscincus* and *Nangura* varying in different genetic analyses (Skinner 2007; Skinner *et al.* 2013) also shows fragmentation and duplication of the temporal scalation, but each secondary temporal overlaps the one below it (Shea pers. obs.).

Greer and Shea (2003) considered the character state of the lower secondary temporal scale overlapping the upper secondary temporal to be apomorphic within the Sphenomorphini, but it has evolved multiple times within that tribe, and given its occurrence in multiple species and genera closely related to *Karma* and *Magmellia*, it is not possible to definitively assign polarity to the character state in *Magmellia*. It does, however, serve as a morphological diagnostic character to differentiate the genus from *Karma*.

I also make a correction to the previous literature on these species. Covacevich and McDonald

(1980) report *M. luteilateralis* as having the fifth supralabial below the centre of the eye and contacting the eye – it is the fourth supralabial (of the six present in both *Karma* and *Magmellia*) that is in this position.

ACKNOWLEDGEMENTS

I thank Scott Eipper for sharing his notes on ventral colour in *Magmellia luteilateralis*, and Elliot Budd for sharing a photograph of ventral colour in this species.

LITERATURE CITED

- Boulenger, G.A. 1887. *Catalogue of the Lizards in the British Museum (Natural History). Volume III. Lacertidae, Gerrhosauridae, Scincidae, Anelytropidae, Dibamidae, Chamaeleontidae.* (Trustees of the British Museum: London).
- Cogger, H.G. 2014. *Reptiles and Amphibians of Australia.* 7th ed. (CSIRO Publishing: Collingwood).
- Couper, P.J., Covacevich, J.A., Marsterson, S.P. & Shea, G.M. 1996. *Coggeria naufragus* gen. et sp. nov., a sand-swimming skink from Fraser Island, Queensland. *Memoirs of the Queensland Museum*, **39**(2): 233-241.
- Covacevich, J. & McDonald, K.R. 1980. Two new species of skinks from mid-eastern Queensland rainforest. *Memoirs of the Queensland Museum*, **20**(1): 95-101.
- Covacevich, J.A., Couper, P.J. & James, C. 1993. A new skink, *Nangura spinosa* gen. et sp. nov., from a dry rainforest of southeastern Queensland. *Memoirs of the Queensland Museum*, **34**(1): 159-167.
- Ehmann, H. 1992. *Encyclopedia of Australian Animals. Reptiles.* (Collins Angus & Robertson: Pymble).
- Fyfe, G. 2008. Skinks. Family Scincidae. Pp. 258-389. In Swan, M. (ed) *Keeping and Breeding Australian Lizards.* (Mike Swan Herp Books: Lilydale).
- Greer, A.E. 1983. The Australian scincid lizard *Calypotis* De Vis: resurrection of the name, description of four new species, and discussion of relationships. *Records of the Australian Museum*, **35**(1): 29-59. <https://dx.doi.org/10.3853/j.0067-1975.35.1983.301>
1986. On the absence of visceral fat bodies within a major lineage of scincid lizards. *Journal of Herpetology*, **20**(2): 265-267. <https://dx.doi.org/10.2307/1563957>
1989. *The Biology and Evolution of Australian Lizards.* (Surrey Beatty & Sons: Chipping Norton).
1992. Revision of the species previously associated with the Australian scincid lizard *Eulamprus tenuis*. *Records of the Australian Museum*, **44**(1): 7-19. <https://dx.doi.org/10.3853/j.0067-1975.44.1992.26>
- Greer, A.E. & Cogger, H.G. 1985. Systematics of the reduce-limbed and limbless skinks currently assigned to the genus *Anomalopus* (Lacertilia: Scincidae). *Records of the Australian Museum*, **37**: 11-54. <https://dx.doi.org/10.3853/j.0067-1975.37.1985.334>
- Greer, A.E. & Shea, G. 2003. Secondary temporal scale overlap pattern: a character of possible broad systematics importance in sphenomorphine skinks. *Journal of Herpetology*, **37**(3): 545-549. <https://dx.doi.org/10.1670/104-02N>
- Kaiser, H., Crother, B.I., Kelly, C.M.R., Luiselli, L., O'Shea, M., Ota, H., Passos, P., Schleip, W.D. & Wüster, W. 2013. Best practices: in the 21st Century, taxonomic decisions in herpetology are acceptable only when supported by a body of evidence and published via peer-review. *Herpetological Review*, **44**(1): 8-23.
- Longman, H.A. 1918. Notes on some Queensland and Papuan reptiles. *Memoirs of the Queensland Museum*, **6**: 37-44.
- O'Connor D. & Moritz, C. 2003. A molecular phylogeny of the Australian skink genera *Eulamprus*, *Gnypetoscincus* and *Nangura*. *Australian Journal of Zoology*, **51**(4): 317-330. <https://dx.doi.org/10.1071/ZO02050>
- Pyron, R.A., Burbrink, F.T. & Wiens, J.J. 2013. A phylogeny and revised classification of Squamata, including 4161 species of lizards and snakes. *BMC Evolutionary Biology*, **13**: 93. <https://dx.doi.org/10.1186/1471-2148-13-93>
- Sadlier, R.A. 1998. Recognition of *Eulamprus tryoni* (Longman), a scincid lizard endemic to the McPherson Ranges of eastern Australia. *Memoirs of the Queensland Museum*, **42**(2): 573-578.
- Skinner, A. 2007. Phylogenetic relationships and rate of early diversification of Australian *Sphenomorphus* group scincids (Scincoidea, Squamata). *Biological Journal of the Linnean Society*, **92**(2): 347-366. <https://dx.doi.org/10.1111/j.1095-8312.2007.00843.x>
- Skinner, A., Hutchinson, M.N. & Lee, M.S.Y. 2013. Phylogeny and divergence times of Australian *Sphenomorphus* group skinks (Scincidae, Squamata). *Molecular Phylogenetics and Evolution*, **69**(3): 906-918. <https://dx.doi.org/10.1016/j.ympev.2013.06.014>
- Swan, G., Sadlier, R. & Shea, G. 2017. *A Field Guide to Reptiles of New South Wales.* 3rd ed. (Reed New Holland: Chatswood).
- Wells, R.W. 2009. Some taxonomic and nomenclatural considerations on the Class Reptilia in Australia. A review of the genera *Eulamprus* and *Glaphyromorphus* (Scincidae), including

- the description of new genera and species. *Australian Biodiversity Record*, **2009**(3): 1-95.
- Wilson, S.K. 2015. *A Field Guide to Reptiles of Queensland*. 2nd ed. (Reed New Holland: Chatswood).
2016. *Reptiles of the Scenic Rim Region*. Scenic Rim Regional Council: Beaudesert).
- Wilson, S.K. & Knowles, D.G. 1988. *Australia's Reptiles. A Photographic Reference to the Terrestrial Reptiles of Australia*. (William Collins: Sydney).
- Wilson, S.K. & Swan, G. 2017. *A Complete Guide to Reptiles of Australia*. 5th ed. (Reed New Holland: Chatswood).
- Specimens examined** (all in Australian Museum):
- Concinnia amplus*: R61482-83 (paratypes); R88015, R111582-91, R114036-38, R126077-78.
- Concinnia tigrina*: R2267, R3981, R16980, R20776, R54801, R59959, R111601, R118638, R128554, R174489.
- Karma murrayi*: R6485 (holotype of *Lygosoma* (*Hinulia*) *tenuis intermedius*, a synonym of *K. murrayi*), R328, R4990, R6469-70, R6472-74, R6484, R7079, R60865 (paratypes of *Lygosoma* (*Hinulia*) *tenuis intermedius*); R137730, R137738-39, R137744, R137748, R137751, R137755, R137766, R137772, R137784-86, R137796-97, R137864, R138305, R138975, R139028, R139057, R139060, R139064-65, R139089, R139222, R139340, R139361, R139489, R139495, R139541, R139543-45, R139632-33, R139668, R139670, R139673, R139720-22, R139727, R139730, R139743, R139757-58, R139784-85, R141537, R141578-79, R141580, R141583-84, R141654, R141658, R141683-84, R142153, R142168, R142173, R142195, R142235, R142328, R142341, R142393, R142411, R142443, R142445, R142447, R142455, R142474, R146106, R148847, R148390-91, R148982-83, R151289, R151785-88, R151791-93, R151797-802, R151860-61, R151904, R151932-33, R151991-2000, R152272-78, R153782, R153792-95, R153804, R153807, R153850, R161359, R161372, R161379, R161846, R172237, R178181-82, R178186, R178191-93, R178230.
- Karma tryoni*: R18704, R85917, R151789-90, R151794-96, R151803-04.
- Magmellia luteilateralis*: R47497, R47763-70, R47855-56, R47841-43 (paratypes); R113923-29, R113950, R114019, R114035.
- Nangura spinosa*: R153027.

Addendum to *Australian Land Snails Volume 2. A Field Guide to Southern, Central and Western Species* by Stanisic, J.; Shea, M.; Potter, D.; Griffiths, O. 2017 (Bioculture Press: Mauritius). 594 pp. ISBN 9789994903832

The official publication dates of this new taxa presented require formal emendation from that provided in the volume due to unforeseen delays in the text becoming freely available. Although printed in 2017 the full print run did not arrive in Australia until mid-2018 and only then, were five copies deposited in internationally renowned libraries as specified by Article 8 of the International Code of Zoological Nomenclature (ICZN). As a result the publication dates of the new taxa introduced in the volume will date from 2018 and not 2017 as was intended. The taxa affected together with their authors and emended dates are given below.

Family CAMAENIDAE

Austrochloritis beecheyi Shea & Griffiths, 2018

Family CHAROPIDAE

Alpiniropa Stanisic, 2018
Ammoniropa Bonham, 2018
Archiropa Bonham, 2018
Austellorien Stanisic, 2018
Banjiropa Stanisic, 2018
Bonhamaropa Stanisic, 2018
Diemenoropa Bonham, 2018
Egilodonta eyrensis Stanisic, 2018
Exquisitiropa Stanisic, 2018
Gadoropa Bonham, 2018
Groveiana Stanisic, 2018
Hyaloropa Stanisic, 2018
Huntiana Stanisic, 2018
Insularopa Stanisic, 2018
Kessneropa Bonham, 2018
Kosciuszkoropa Stanisic, 2018
Lacuropa Stanisic, 2018

Lorelleia Stanisic, 2018
Lottaropa Bonham, 2018
Meredithena Stanisic, 2018
Metaropa Stanisic, 2018
Minutiropa Stanisic, 2018
Nanoropa Stanisic, 2018
Nullarboropa Stanisic, 2018
Nullarboropa granulosa Stanisic, 2018
Protractiropa Stanisic, 2018
Robinsoniana Stanisic, 2018
Tasmanoropa Bonham, 2018
Tasmathera Bonham, 2018
Tateropa Stanisic, 2018
Whissonia Stanisic, 2018

Family PUNCTIDAE

Gratilaoma aslini Stanisic, 2018
Gratilaoma globula Stanisic, 2018
Tescilaoma Stanisic, 2018
Tescilaoma erugata Stanisic, 2018
Tescilaoma excavata Stanisic, 2018

Family RHYTIDIDAE

Emmalena Stanisic, 2018

Consequently, new genera and species published in this field guide should be cited as illustrated below:

Protractiropa Stanisic, 2018 in Stanisic *et al.* 2018.

Egilodonta eyrensis Stanisic, 2018 in Stanisic *et al.* 2018.

Dr. John Stanisic, Honorary Research Fellow, Queensland Museum, PO Box 3300 South Brisbane, Qld 4101, Australia.

<https://doi.org/10.17082/j.2204-1478.61.2019.2018-13>

LSID urn:lsid:zoobank.org:pub:E4A4D28E-875C-454D-BC1C-F1016AFE51D5

